



An annotated list of fish parasites (Copepoda, Monogenea, Digenea, Cestoda and Nematoda) collected from Emperors and Emperor Bream (Lethrinidae) in New Caledonia further highlights parasite biodiversity estimates on coral reef fish

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Abstract

Parasites were collected from 17 species of emperors and emperor bream (Lethrinidae) in the waters off New Caledonia, South Pacific. Host-parasite and parasite-hosts lists are provided, with a total of 188 host-parasite combinations (11 per fish species), including 81 identifications at the species level. A total of 52 parasites were identified at the species level, and 40 new host records were found. Results are presented for larval isopods, copepods (16 species), monogeneans (24), digeneans (27), cestodes (11) and nematodes (10). When results were restricted to the four best-sampled fish species for which more than 30 specimens were examined, the number of host-parasite combinations was 22.25 per fish species, and the number of parasite taxa identified at the species level was 9.5 per fish species. From these data, the total number of metazoan parasite species predicted from all lethrinid species of New Caledonia, based on a classification of fish sizes using length in three categories, is 340, i.e. 13 per fish species. A biogeographical comparison with Heron Island on the Great Barrier Reef (Queensland, Australia) was possible only for a single fish species, *Lethrinus miniatus*: in a total of 65 host-parasite combinations, only five taxa identified at the species level (three monogeneans and two digeneans) were shared at both localities. Parasite biodiversity in lethrinids was of similar magnitude to that in groupers (Serranidae Epinephelinae) in the same area, and this study confirms a previous prediction of 10 parasite species per coral reef fish species. Although this study required significant sampling and identification, we estimate that only 13% of the parasites of lethrinids are known in New Caledonia.

Key words: fish, new host records, new geographical records, inventory, biogeography, South Pacific

Résumé

Les parasites ont été récoltés chez 17 espèces de bossus et bec de canes (Lethrinidae) en Nouvelle-Calédonie, Pacifique Sud. Des listes hôtes-parasites et parasites-hôtes sont fournies, avec un total de 188 combinaisons hôtes-parasites (11 par espèce de poisson), y compris 81 identifications au niveau spécifique. Un total de 52 parasites a été identifié au niveau spécifique, et 40 nouvelles mentions d'hôtes ont été trouvées. Les résultats concernent les isopodes larvaires, les copépodes (16 espèces), monogènes (24), digènes (27), cestodes (11) et nématodes (10). Quand les résultats sont restreints aux quatre espèces de poissons les mieux échantillonnées, pour lesquelles plus de 30 spécimens ont été examinés, le nombre de combinaisons hôtes-parasites est de 22,25 par espèce de poisson, et le nombre de taxons de

parasites identifiés au niveau spécifique est de 9,5 par espèce de poisson. A partir de ces données, le nombre total d'espèces de parasites métazoaires prédit pour l'ensemble des espèces de Lethrinidae de Nouvelle-Calédonie, basé sur une classification des tailles de poissons en trois catégories, est de 340, c'est-à-dire 13 par espèce de poisson. Une comparaison biogéographique avec Heron Island sur la Grande Barrière de Corail (Queensland, Australie) a été possible pour une seule espèce, *Lethrinus miniatus*, et parmi un total de 65 combinaisons hôtes-parasites, seulement cinq taxa identifiés au niveau spécifique (trois monogènes et deux digènes) ont été trouvés en commun dans les deux localités. La biodiversité parasitaire chez les Lethrinidae est de magnitude comparable à celle des loches (Serranidae Epinephelinae) dans la même région, et cette étude confirme une prédiction précédente de 10 espèces de parasites par espèce de poisson de récif corallien. Bien que cette étude ait demandé un effort significatif d'échantillonnage et d'identification, nous estimons que seulement 13% des parasites de Lethrinidae sont connus en Nouvelle-Calédonie.

Introduction

Biodiversity in coral reefs, i.e. the number of different species, is huge (Reaka-Kudla 1997), but the biodiversity of parasites of coral reef fish is extremely poorly known. Rohde (1976) predicted 20,000 parasite species (including metazoans and protozoans) for the 1,000 fish species in the vicinity of Heron Island, Great Barrier Reef, Australia. From a detailed systematic study of parasites of serranids (groupers), Justine *et al.* (2010) predicted about 10 species of metazoan parasites per fish species, with a total of 410 metazoan parasite species for the 41 grouper species in New Caledonia. Moreover, they extrapolated these results for all fish species of the New Caledonia lagoon and predicted a total parasite biodiversity of 17,000 species. However, a compilation of 107 publications on the parasite fauna of New Caledonia Justine (2010) provided a list of only 371 species of fish parasites, meaning that only 2% of the total predicted parasite biodiversity is recorded.

In this paper, we present results obtained from a single family of coral reef fishes, the Lethrinidae (Emperors and Emperor Bream) in an area centred around Nouméa, New Caledonia. The Lethrinidae is almost restricted to the Indo-Pacific Ocean (with a single species in the Eastern Atlantic); they represent an important source of food in Australia and elsewhere, with more than 100,000 tonnes caught in 2008 in the Indo-Pacific (FAO 2010). In New Caledonia, the biodiversity and abundance of lethrinids is remarkably high (Laboute & Grandperrin 2000) and lethrinids are very popular fish for human consumption; one species, *L. miniatus*, is sometimes discarded due to the risk of ciguatera poisoning (Carpenter & Allen 1989; Laboute & Grandperrin 2000), but most other species are consumed.

Results are presented as a host-parasite list (Appendix 1), in which all parasites of a given host species are listed, and a parasite-host list (Appendix 2), in which all hosts are listed for each parasite species. A list of specimens deposited in various international collections is also provided (Appendix 3) with accession numbers. The current dataset includes 17 species of lethrinid hosts.

Justine *et al.* (2010) emphasized the difficulty of expressing the number of parasite species found because of the many cases of unidentified species, which can represent a generalist species or a number of cryptic – or difficult to identify – species. In this study, we maintain the same conventions and strictly minimize the numbers by counting all cases of unidentified species in a group as a single taxon. We found 91 parasite taxa (1 Isopoda, 16 Copepoda, 24 Monogenea, 27 Digenea, 11 Cestoda, 10 Nematoda, 1 Acanthocephala and 1 Hirudinea). The total number of host-parasite combinations recorded (i.e. a parasite species associated with a host species) is 188, including 81 occasions where the parasite was identified at the species level. A total of 42 parasites was identified to species, and 40 new host records were found.

A comparison with other studies of lethrinid parasites in other locations would be of interest for biogeography and our understanding of the distribution of parasites of coral reef fish. For serranids, Justine *et al.* (2010) found that very few data sets were available, and they could compare only the parasite faunas of four grouper species between New Caledonia and Heron Island, Queensland, Australia, based on the compilation of Lester & Sewell (1989). For lethrinids, the literature is also extremely scarce and we could only compare our results in New Caledonia with Heron Island, for a single fish species.

Material and methods

Methods used in this study were generally similar to those used for serranid parasites (Justine *et al.*, 2010). Although maximum care was taken during the collection of parasites and their taxonomic identification, we draw attention to some flaws and weak points in our sampling to avoid inappropriate interpretation of negative results.

Collection of hosts. Over a seven-year period (2003-2009), fish were collected mostly by fishing with hook and line, sometimes by spear-fishing and occasionally from the fish market in Nouméa. All specimens came from within the lagoon, the barrier reef or the outer reef slope within a radius of ca. 30 km around Nouméa. A marked difference between the origin of the fish was that most lethrinids came from within the lagoon (depth 10-35 m) but specimens of *L. miniatus* were fished on the external slope of the barrier reef (depth 60-150 m) (Fourmanoir 1977; Laboute & Grandperrin 2000). Live fish were kept in a container with seawater and immediately brought back to the laboratory. All fish were measured, weighed and photographed. A unique number (JNC) was assigned to each fish. The parasitological material was then assigned a corresponding JNC number linked to the respective fish host. Measurements of hosts were taken for possible future comparison of parasite prevalence and host age with other localities and because the monogenean fauna has been shown to change according to fish size (Hinsinger & Justine 2006; Sigura & Justine 2008). However, for brevity these data are not given in this paper. Host names have been updated using FishBase (Froese & Pauly 2010); special difficulties in the nomenclature of lethrinids are outlined below. All *Gymnocranius* specimens were identified by Philippe Borsa (IRD) from photographs to help differentiate the rare and newly discovered species (Borsa *et al.* 2010).

Collection of parasites. We used two methods that targeted two different sets of organs, here designated as the ‘gills’ and the ‘abdominal organs’. The two methods were sometimes used on the same fish individual, but often fish were processed only with one method. There are several reasons for this. Often, a given fish species was examined for small gill monogeneans (with other gill parasites collected incidentally) until the monogeneans were collected and described. The collection of monogeneans was so time-consuming that detailed study of other organs was impractical. Later when the small monogeneans were described, individuals of the same fish species were processed in detail for ‘abdominal organs’, but the gills of these specimens were not carefully examined for monogeneans. In the host-parasite list (Appendix 1) and in Table 1, we counted separately the total number of fish collected, and the number of fish examined for ‘gills’ and for the ‘abdominal organs’; ideally, the latter two numbers should equal the first, but they rarely do. These numbers however are important in understanding the significance of the results, especially when few parasites were collected from a few fish examined.

For the ‘gill method’, all gill arches from both sides were removed one by one by cutting them at their extremities and they were examined immediately in seawater. Parasites were collected under a binocular microscope. Monogeneans were removed alive with fine needles and immediately prepared for slides (Justine 2005). Copepods and isopods were removed with fine forceps or with the help of a fine needle, and immediately fixed in 70% ethanol. Live gnathiid isopod larvae were sometimes kept in seawater in an attempt to obtain adults (Ota & Hirose 2009a;b; Smit *et al.* 2003), but these failed to result in adults.

For the ‘abdominal organ method’, the body cavity was opened and all organs were removed. The liver and gonads were separated. The stomach, caeca and intestine were then opened longitudinally with scissors. For about half of the fish (2003-2006), the digestive tract was examined under a binocular microscope and the parasites were removed with fine forceps or a pipette. For the other half (2007-2009), we used the ‘gut wash method’ (Cribb & Bray 2010) in saline (1/4 seawater, 3/4 tap water); this method proved to be more effective and faster than the direct examination method. Cystidicolid nematodes, which are especially thin, were searched for using the ‘gut wash method’; we noticed that they were more easily found and still alive when the gut was kept in a refrigerator overnight. Transversotrematid digeneans, which are under the scales, were sometimes searched for by soaking the fish in saline for an hour and then examining the bath. The gonads were often, but not always, examined under a binocular microscope and were macerated in a small quantity of saline. Cysts of trypanorhynch cestodes were carefully opened with two pairs of fine forceps in saline under a

binocular microscope, and the living larvae were immediately flattened between two slides or pipetted into boiling saline, to obtain everted tentacles. Digeneans and cestodes from the intestinal lumen were pipetted alive in near-boiling saline. Copepods were examined and dissected according to routine methods (Boxshall *et al.* 2008). Permanent slides were made of monogeneans, digeneans and cestodes according to routine methods (Beveridge *et al.* 2007; Bray & Justine 2006; Justine 2005, respectively). Nematodes were fixed alive in near-boiling 4% formalin, or sometimes in boiling 70% ethanol or near-boiling saline, and later examined in glycerine; specimens were also prepared for scanning electron microscopy (Moravec & Justine 2010). Tetraphyllidean cestode larvae, which are impossible to identify morphologically, were generally fixed in near-boiling saline and kept in absolute ethanol for possible future molecular analysis.

Several organs were almost never examined. For possible comparison with other geographic localities or similar future studies in the same location, it is important that we explicitly describe the flaws in our sampling methods. Parts of the fish almost never examined include the branchiostegal membranes, the fins and the general surface of the body and head; this certainly decreased our findings of capsalid monogeneans (e.g. Rohde *et al.* 1994) and philometrid nematodes. The heart and blood system were almost never examined, and thus no aporocotylid digenean was recorded. The kidneys, the liver, the general muscle mass and the bones were not examined. The nasal cavities were not opened. No metacercariae were sought in the muscle mass. Anisakid nematode larvae, which are often numerous on the surface of all internal organs, were only occasionally collected. The eyes and the orbits were examined in certain cases, but certainly not extensively. Only parasitic crustaceans and helminths are recorded here, and no attempt was made to seek microscopic protistan or myxozoan parasites; however, we do mention a few cases of microsporidian cysts which were visible with the naked eye. The absence in the present results of several parasitic groups which are usually found in the neglected organs cited above is thus not significant. However, the absence of copepods on the skin is significant, because such parasites are easily spotted at the time of catch and were collected on fishes from other families.

The number of parasite specimens collected has generally been recorded, but for brevity is not mentioned in this study, which focuses on species-level biodiversity.

Identification of parasites. The specimens, generally collected by J.-L. Justine and his team of students, and sometimes by visiting colleagues, were forwarded to respective specialists: I. Beveridge (trypanorhynch cestodes), G. A. Boxshall (copepods), R. A. Bray (digeneans), F. Moravec (nematodes), I. D. Whittington (capsalid monogeneans), J.-L. Justine (other monogeneans). The names of cestode orders and suborders follow Khalil *et al.* (1994), updated by Kuchta *et al.* (2008), Healy *et al.* (2009) and Olson *et al.* (2010). Polyopisthocotylean and monopisthocotylean monogeneans are treated as two independent groups, because monophyly of the monogeneans is not established (Jovelín & Justine 2001; Justine 1998; Mollaret *et al.* 1997, 2000; Perkins *et al.* 2010). However, since polyopisthocotyleans were rare, results for both groups were occasionally pooled. The monogeneans in *Haliotrema* Johnston & Tiegs, 1922, sometimes included in the Dactylogyridae, are here considered as members of the Ancyrocephalidae following Lim *et al.* (2001). Many specimens have been deposited in recognized collections (Appendix 3); other specimens under study are still in the collections of the various authors but will be eventually deposited in the collection of the Muséum national d'Histoire naturelle, Paris, France (MNHN) and/or in other recognized, curated collections.

Many specimens were not identified to species level, even in groups in which this is theoretically possible. Publication of this list could be delayed for several years to await better and more comprehensive accuracy. However, it was considered that enough significant data had already been accumulated to warrant publication. Data presented here were compiled in May 2010; results which were not in press at this date have not been included.

New host records have been found by comparison with available lists or databases (Gibson *et al.* 2005; Palm 2004). Given the paucity of parasitological studies in New Caledonia (Justine 2010), most new records are new geographic records and are not indicated as such.

Abbreviations for higher parasite taxa

The following abbreviations are used in Tables and Appendices.

For all: **Unid:** Unidentified family.

Isop: Isopoda; Families: **Gnat:** Gnathiidae;

Cope: Copepoda; Families: **Cali:** Caligidae; **Diss:** Dissonidae; **Hats:** Hatschekiidae; **Lern:** Lernanthropidae; **Lerp:** Lernaepodidae; **Penn:** Pennellidae

Mono: Monogenea; **Monop:** Monopisthocotylea; **Poly:** Polyopisthocotylea; Families: **Ancy:** Ancyrocephalidae; **Caps:** Capsalidae; **Dipl:** Diplectanidae; **Micr:** Microcotylidae.

Dige: Digenea; Families: **Acan:** Acanthocolpidae; **Bive:** Bivesiculidae; **Didy:** Didymozoidae; **Hemi:** Hemiuridae; **Opec:** Opecoelidae; **Tran:** Transversotrematidae; **Zoog:** Zoogonidae.

Tryp: Cestoda Trypanorhyncha; Families: **Eute:** Eutetrarhynchidae; **Laci:** Lacistorhynchidae; **Otob:** Otobothriidae; **Tent:** Tentaculairidae.

Both: Cestoda Bothriocephalidea (no family identified).

Tetr: Cestoda Tetraphyllidea (no family identified).

Nema: Nematoda; Families: **Anis:** Anisakidae; **Cama:** Camallanidae; **Cucu:** Cucullanidae; **Cyst:** Cystidicolidae; **Gnto:** Gnathostomatidae; **Phil:** Philometridae; **Tric:** Trichosomoididae.

Acantho: Acanthocephala (no family identified).

Hiru: Hirudinea (no family identified).

Abbreviations in text and tables presenting biodiversity analyses.

NHR: New host record; **HPC:** Host-parasite combination; **SLIP:** Species-level identified parasite; **SLIP-HPC:** Species-level identified parasite – host-parasite combination.

Institutional abbreviations: BMNH, Natural History Museum, London, United Kingdom; HCIP, Helminthological Collection, Institute of Parasitology, Biology Centre, Academy of Sciences of the Czech Republic, České Budějovice, Czech Republic; MNHN, Muséum national d'Histoire Naturelle, Paris, France; SAMA AHC, South Australian Museum Adelaide, Australian Helminthological Collection, Adelaide, Australia; USNPC, United States National Parasite Collection, Beltsville, USA.

Results and discussion

Results are presented as a host-parasite list (Appendix 1), a parasite-host list (Appendix 2) and a list of material deposited (Appendix 3). The number of HPCs and the number of SLIP-HPCs found in each fish species are given in Table 1.

Comments on each group. In these brief comments, we discuss the new records and analyse our findings from the perspective of a numerical evaluation of biodiversity and we attempt to understand the significance of the number of species found in terms of actual parasite biodiversity.

Fish. Seventeen species of lethrinids were examined. Fricke & Kulbicki (2007) listed 23 nominal species present in New Caledonia, including 15 species of *Lethrinus*; with the very recent differentiation of three additional species of *Gymnocranius* (Borsa *et al.* 2010; Justine & Briand 2010), there are now 26 nominal species. Our 17 examined species thus represent 65% of the total number of lethrinid species present in New Caledonia.

Taxonomically, lethrinids are considered one of the most problematic of tropical marine fish families (Carpenter & Allen 1989). Several species which were examined for parasites by previous authors have had name changes (see Randall & Wheeler 1991, and Table 2). One of the most abundant species, *L. rubrioperculatus* Sato, 1978 was described recently (Sato 1978), and the last few years have seen new records (Béarez 2003) and the description of *L. ravus* Carpenter & Randall, 2003, *G. oblongus* Borsa, Béarez & Chen, 2010, and the differentiation of *Gymnocranius* sp. B and sp. C (Borsa *et al.* 2010; Carpenter & Randall 2003). The work of the parasitologist is complicated by these new species of fish: two of the nematode species described by this team in recent years from a single species of *Gymnocranius* were in fact from several fish species; these 'new' records are updated in Appendices 1 and 2.

TABLE 1. Number of host-parasite combinations (HPCs) found in 17 species of lethriniids in New Caledonia. For each number: HPCs (SLIP-HPCs) i.e. number of host-parasite combinations, and, within parentheses, number of species level identified parasite – host-parasite combinations.

Number of fish examined				Number of HPCs and SLIP-HPCs (within parentheses)										
Fish Species	Total	Gill	Abdomen	Isop	Cope	Mono	Poly	Dige	Both	Tetr	Tryp	Nema	Other	Total
<i>Gnathodentex aurolineatus</i>	3	3	0			1(0)								1(0)
<i>Gymnocranius euanus</i>	74	38	60		4(2)	4(2)	1(0)	10(4)		1(0)	1(0)	2(1)		23(9)
<i>Gymnocranius grandoculis</i>	15	15	11	1(0)	5(3)	5(3)	1(0)	6(2)			1(1)	3(2)		22(11)
<i>Gymnocranius oblongus</i>	4	4	2		1(1)	2(1)	1(0)	3(2)				1(1)		8(5)
<i>Gymnocranius</i> sp. B	4	3	2			4(3)		3(3)				1(0)		8(6)
<i>Gymnocranius</i> sp. C	2	1	2					1(0)				1(1)		2(1)
<i>Lethrinus atkinsoni</i>	24	21	14	1(0)		1(1)		3(2)		1(0)				6(3)
<i>Lethrinus genivittatus</i>	127	46	118	1(0)		1(0)		7(2)		1(0)	2(1)	4(2)		16(5)
<i>Lethrinus harak</i>	8	8	2	1(0)	1(0)	7(3)		2(0)					1(0)	12(3)
<i>Lethrinus lentjan</i>	9	9	7	1(0)		3(2)		2(1)				1(0)		7(3)
<i>Lethrinus miniatus</i>	31	15	27	1(0)	3(1)	6(3)		10(7)	1(0)	1(0)	4(4)	4(1)	1(0)	31(16)
<i>Lethrinus nebulosus</i>	14	8	14		3(1)	5(3)	1(0)	1(1)		1(0)*				11(5)
<i>Lethrinus obsoletus</i>	3	3	3	1(0)	1(1)	3(1)								5(2)
<i>Lethrinus ravus</i>	3	2	1	1(0)		2(1)		1(0)				1(0)		5(1)
<i>Lethrinus rubrioperculatus</i>	97	49	66	1(0)	2(2)	5(1)		8(3)		1(0)	2(2)		1(0)	20(8)
<i>Lethrinus variegatus</i>	7	4	5			1(0)		2(0)		1(0)		3(2)		7(2)
<i>Lethrinus xanthochilus</i>	1	1	0		1(0)	3(1)								4(1)
Total (17 species)	423	227	334	9(0)	21(11)	53(25)	4(0)	59(27)	1(0)	7(0)	10(8)	21(10)	3(0)	188(81)

* For Tetraphyllidea, indicates a record identified as Lecanicephalidea; ‘Other’ includes Acanthocephala and Hirudinea.

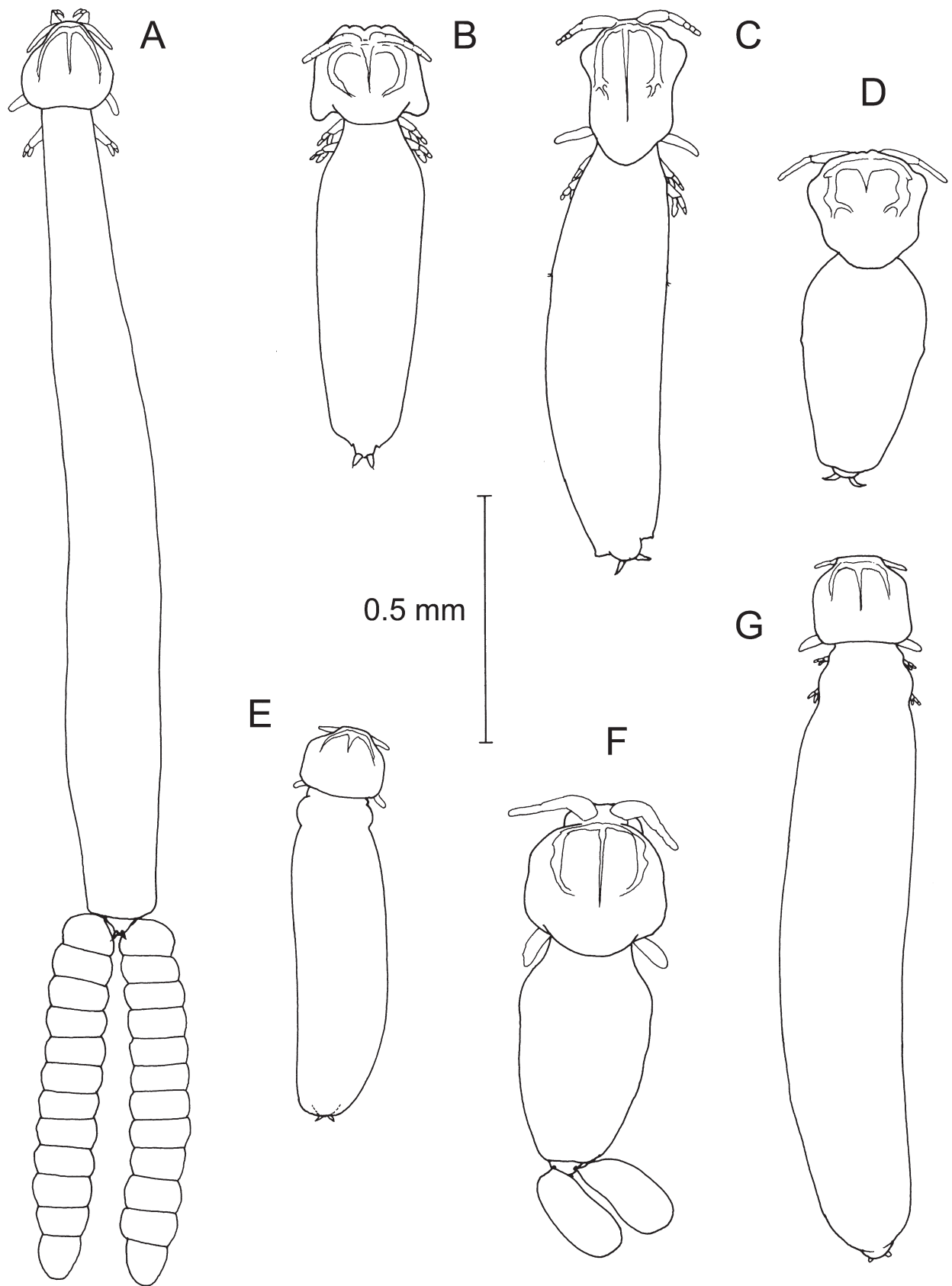


FIGURE 1. Species of *Hatschekia* collected from lethrinid hosts, all drawn to same scale. **A.** *Hatschekia gracilis* Yamaguti, 1954; **B.** *Hatschekia* new species 12; **C.** *Hatschekia* cf. *elegans* Kabata, 1991; **D.** *Hatschekia* new species 16; **E.** *Hatschekia* new species 13; **F.** *Hatschekia* new species 14, **G.** *Hatschekia* new species 15.

The Lethrinidae is composed of two subfamilies (Carpenter & Allen 1989), the Monotaxinae (including *Gymnocranius*, *Monotaxis* and the monotypic *Gnathodentex* and *Wattsia*) and the Lethrininae (including only the species-rich *Lethrinus*). We examined species from both subfamilies; Justine & Briand (2010) outlined the differences in monogenean fauna between them. Our analysis, however, lacks members of *Monotaxis* and *Wattsia*. Large (n>30) samples of fish were collected for at least four species (*L. genivittatus*, *L. miniatus*, *L. rubrioperculatus*, and *G. euanus*), but only a few specimens of *L. nebulosus* were examined, although this species is one of the most important species for fisheries in New Caledonia (Borsa *et al.* 2009).

With the newly described lethrinid species, there are now 41 species of Lethrinidae globally, and the 17 species investigated here thus represent 41% of the world fauna.

TABLE 2. Taxonomic issues with Lethrinidae and the fish names used in parasitological literature (limited to those species also examined in New Caledonia).

Fish name in original reference	Updated host name	Parasite	Reference	Comments
<i>Lethrinus chrysostomus</i>	<i>Lethrinus miniatus</i>	<i>Calydiscoides</i> spp.	Young 1969	See Justine 2007c
<i>Lethrinus mahsena</i>	<i>Lethrinus atkinsoni</i>	<i>Calydiscoides rohdei</i>	Oliver 1984	See Justine 2007c
<i>Gymnocranius euanus</i>	A mixture of <i>G. euanus</i> and <i>G. sp. C</i>	<i>Ascarophisnema tridentatum</i>	Moravec & Justine 2010	Updated in this paper
<i>Gymnocranius grandoculis</i>	A mixture of <i>G. grandoculis</i> and <i>G. oblongus</i>	<i>Huffmanella longa</i>	Justine 2007a	Updated in this paper

Isopoda. All larval isopods found belonged to the Gnathiidae. Larvae cannot be identified at the species level and thus are here considered as a single taxon, but there are likely to be several species present. They were found on the gills of nine of the 17 fish species investigated. Since gnathiid praniza larvae show low host specificity, it is tempting to hypothesize that all lethrinids may harbour them; however, their absence from the gills of 38 *G. euanus* specimens examined in this study suggests that this is not the case, and some fish species may actually be devoid of gnathiid larvae for some unknown reason, a rather unexpected result. Justine *et al.* (2010) found gnathiid larvae on gills of 12 of the 28 grouper species examined in New Caledonia and considered that they were probably present on all species.

No adult isopod was found from any of more than 400 lethrinids examined, certainly a significant result. Apparently only one record of an adult isopod on a lethrinid exists in the literature, *Anilocra leptosoma* Bleeker on an unidentified *Lethrinus* in the Red Sea (Monod 1933).

Copepoda. Sixteen ‘species’ of adult copepods were recorded, and belonged to the Caligidae (3 species), Dissonidae (1), Lernaepodidae (1), Lernanthropidae (1) and Hatschekiidae (9 species).

Most species were collected from the gills, and none was from the external surface of the body. One species, the lernaepodid *Parabrachiella* sp., was from an unusual microhabitat, the pharyngeal teeth of *G. euanus*. This same microhabitat is shared by the capsalids *Encotyllabe* spp. Only a single female *Parabrachiella* sp. was found, without a dwarf male attached, and more material is required for identification and description.

The finding of *Dissonus excavatus* on *L. miniatus* confirms the tendency of this species to prefer large hosts (Boxshall *et al.* 2008), and adds a new species and family of hosts for this species, previously recorded only from the labrid *Bodianus perditio* (Quoy & Gaimard) and the lutjanid *Macolor niger* (Forsskal) (Boxshall *et al.* 2008). This species is known from the waters around Taiwan as well as from New Caledonia.

Numerous specimens of hatschekiids were collected. Four described species were found, but the other specimens represent five new species. Species were numbered in sequence with previously undescribed new species reported in Justine *et al.* (2010). *Hatschekia gracilis* Yamaguti, 1954 (Fig. 1A) was found on two hosts, *L. nebulosus* and *L. obsoletus*. This extremely elongate species was originally described from an unidentified *Lethrinus* host caught off Sulawesi (Yamaguti 1954). *Lethrinus miniatus* in New Caledonia serves as host to a species of *Hatschekia* that closely resembles *H. elegans* as described by Kabata (1991)

from *L. miniatus* (as *L. chrysostomus* Richardson) caught off Heron Island, Australia. *H. elegans* has a uniquely elongated head which carries finely spinulate protuberances on its lateral margins. The material from *L. miniatus* in New Caledonia has the same characteristic head shape and carries spinulate protuberances laterally (Fig. 1C), but the body is considerably longer. Body length is known to vary according to the state of contraction, especially in fixed material, but until further studies are made this species is referred to as *Hatschekia* cf. *elegans*. Three as yet undescribed new species are also found on species of *Lethrinus*: *Hatschekia* sp. 16 (Fig. 1D) on *L. miniatus*, *Hatschekia* sp. 13 (Fig. 1E) on *L. nebulosus*, and *Hatschekia* sp. 15 (Fig. 1G) on *L. harak* and *L. nebulosus*.

Gymnocranius species serve as hosts for four species of *Hatschekia*, two of them new. The broad-bodied species *H. rotundigenitalis* Yamaguti, 1939 was found on both *G. euanus* and *G. grandoculis*. This species utilizes other congeneric hosts including *G. griseus* (Temminck & Schlegel) in Japanese waters (Yamaguti 1939) and *G. audleyi* Ogilby in Australian waters, off Heron Island (Kabata 1991). *H. megacephala* Kabata, 1991 was originally described from *G. audleyi* Ogilby off Heron Island. *G. grandoculis* is a new host record. The new species *Hatschekia* sp. 12 was recorded only from *G. euanus*, and *Hatschekia* sp. 14 (Fig. 1F) only from *G. grandoculis*. *Hatschekia* sp. 12 (Fig. 1B) resembles *H. crenata* Hewitt, 1969, from New Zealand and *H. crenulata* Kabata, 1991 from Australian waters, in the possession of a crenate anterior margin to the cephalothorax, however the new species can be readily distinguished by the presence of well developed posterolateral lobes on the cephalothorax.

Three sea lice belonging to *Caligus* Müller, 1785 were found. *Caligus novocaledonicus* Kabata, 1968 was common on both *G. euanus* and *G. grandoculis*, and also occurred on *G. oblongus*. All three are new host records. Interestingly it did not occur on the sampled material of *L. miniatus*, its type host in New Caledonian waters (Kabata 1968). *C. lethrinicola* Boxshall & El-Rashidy, 2009 occurred only on *L. rubrioperculatus* (Boxshall & El-Rashidy 2009). The third *Caligus* is a new species, and is characterised by its crescent-shaped genital complex and by the extreme development of the fifth legs. It is the same new species as previously reported by Justine *et al.* (2010) from the serranid host *Epinephelus fasciatus*.

The lemanthroid *Sagum vespertilio* Kabata, 1979 was originally described from *L. laticaudis* Alleyne & Macleay (as *L. fletus* Whitley) in Australian waters off Queensland (Kabata 1979). Here it was found on the gills of *L. rubrioperculatus*, a new host record.

Monogenea. We found few polyopisthocotylean monogeneans and a number of monopisthocotylean monogeneans from three families, the Ancyrocephalidae, Capsalidae and Diplectanidae.

Polyopisthocotylean monogeneans were rare and often represented by single immature microcotylid specimens, which were not identified. Even though polyopisthocotyleans may be host specific, some microcotylid species are known to share host species in the same genus (e.g. Catalano *et al.* 2010). Here, we adopt a cautious approach and estimate that polyopisthocotyleans recovered from lethrinids represent a single species.

The Ancyrocephalidae include species from the gills, reported here as *Haliotrema* spp. but which probably represent an independent genus, unique to lethrinids, characterised by two prominent glandular reservoirs in the haptor (similar described species are *H. fleti* Young, 1968, *H. chrysostomi* Young, 1968 and *H. lethrini* (Yamaguti, 1937) Young, 1968, all from lethrinids (Young 1968)). These were found on nine species of *Lethrinus*. Interestingly, no *Gymnocranius* had these ancyrocephalids (Justine & Briand 2010). From a preliminary morphological examination, we estimate that there are at least five different '*Haliotrema*' species on lethrinids of New Caledonia.

The Capsalidae reported here include species from the 'body surface' (including branchiostegal membranes, skin of the body and head) and from a specialized microhabitat, the pharyngeal teeth (*Encotyllabe* spp.). Molecular analyses of a broad range of capsalid species indicate that the current morphological classification (Whittington 2004) corresponds little with phylogenetic relationships based on three unlinked nuclear genes (Perkins *et al.* 2009). The systematics of capsalids is therefore currently under reinvestigation (e.g. Whittington 2010). Most capsalids in this study could not be identified reliably at the species or in some cases even at the generic level, based on morphological characters because the molecular phylogeny of Perkins *et al.* (2009) indicates a high frequency of apparent homoplasy among key

morphological characters. This has clouded the definitions of several genera with representatives of some showing polyphyly. An obvious effect of these systematic uncertainties is reluctance to assign some capsalid species to genera until more is known and understood about important morphological characters appropriate to differentiate genera. For this study, several capsalid species have been characterized by molecular methods (Perkins 2010). There are at least four species from the ‘body surface’ (taxa differentiated by nuclear and mitochondrial markers, but not formally named, i.e. Capsalidae sp. 8, sp. 10, sp. 11, sp. 16 of Perkins, 2010) and two *Encotyllabe* species, probably one in *Lethrinus* spp. (*Encotyllabe caballeroi*, *Encotyllabe* sp. 1 of Perkins, 2010) and one in *Gymnocranius* spp. (*Encotyllabe* sp. 2, *Encotyllabe* sp. 3 of Perkins, 2010). Interestingly, no capsalid was found on the gills of any of the lethrinid species investigated.

Rohde *et al.* (1994) studied the assemblage of ectoparasites from the gills and head of *L. miniatus* from three localities on the Great Barrier Reef, Australia. Like our study, no capsalid was found on the gills of *L. miniatus* by Rohde *et al.* (1994) but five capsalid Monogenea were reported including *E. caballeroi* from the pharyngeal ‘plates’ and four taxa termed Benedeniinae sp. A, sp. B, sp. C and sp. E from ‘head sediment’ and/or ‘lip folds’, all identified by I.D. Whittington. The reason that specific sites were rarely attributed to capsalids by Rohde *et al.* (1994) is because the benedeniine specimens detached from the severed fish heads during processing and fixation in formalin. Specimens of *E. caballeroi* remained attached to the pharyngeal teeth but it is likely that Benedeniinae sp. A, sp. B, sp. C and sp. E of Rohde *et al.* (1994) may resemble Capsalidae sp. 8, sp. 10, sp. 11 and sp. 16 of Perkins, 2010 from the ‘body surface’, especially from the branchiostegal membranes and skin of the head of lethrinids studied from New Caledonia. The intensity of infection for capsalids from the head was low on *L. miniatus* in the study of Rohde *et al.* (1994) and we found very few specimens in our study. Preliminary observations by Whittington (unpublished) on capsalids from the heads of lethrinids caught off the Great Barrier Reef and off New Caledonia indicate this assemblage may represent an independent genus (or genera), unique to lethrinids, characterised by specialised morphology associated with the reproductive system. Diagnosis and description of these taxa must await the collection of more material. It is not known whether the undescribed capsalids from the external head surfaces of lethrinids are species-specific or whether they may be shared across lethrinid genera as may be the case for *Encotyllabe* spp. (see above).

The Diplectanidae represents the major monogenean family in the lethrinids, with 11 species in two genera, *Calydiscoides* (restricted to *Lethrinus* spp. [Lethrininae]) and *Lamellodiscus* (restricted to *Gymnocranius* and *Gnathodentex* [Monotaxinae]). *Calydiscoides* has seven species and *Lamellodiscus* has four species, including a species described but not formally named from *Gn. aureolineatus*. Justine & Briand (2010) discussed the distribution of species of these two genera in the lethrinids, nemipterids and sparids.

Although diplectanids often show strict host specificity (Justine 2007b; Justine *et al.* 2010; Oliver 1987), several species of *Calydiscoides*, such as *C. difficilis* and *C. duplicostatus*, display relatively wide specificity, with five and three *Lethrinus* species as hosts, respectively; however, Rascalou & Justine (2007) mentioned morphometric differences between the specimens from different fish and did not exclude the possibility of additional cryptic, species-specific, *Calydiscoides* species. For *Lamellodiscus*, the situation is similar, with *La. magnicornis* and *La. parvicornis* in respectively four and three species of *Gymnocranius*. It is noteworthy that species of *Gymnocranius*, including the newly four described or undescribed species (Borsa *et al.* 2010), cannot be distinguished by their monogenean fauna.

With the above evaluation of numbers of species for each family, the minimum total of monogenean taxa in lethrinids is 24 species (23 monopisthocotyleans and 1 polyopisthocotylean).

Digenea. Twenty-seven taxa of digeneans were recorded, but this number is greatly reduced by juvenile and adult didymozoids being counted each as a single taxon.

Didymozoid juveniles were found in the intestine of three species. These are found in many families of fish, including lethrinids (Parukhin 1976), and are impossible to identify to species level, although different ‘forms’ can be differentiated (Pozdnyakov & Gibson 2008). Certainly, these juveniles represent a number of species.

Adult didymozoids were found in the flesh of five fish species. These have tangled filiform bodies which are difficult to prepare for slides. It is not known whether these represent a single species or several; records of adult didymozoids from lethrinids are scarce in the literature (Araki & Machida 1994; Lester & Sewell 1989) and apparently no species from lethrinids has been described (Pozdnyakov & Gibson 2008).

In addition to the didymozoids, the six digenean families represented include the species-rich Opcoelidae, and the Acanthocolpidae, Bivesiculidae, Hemiuridae, Transversotrematidae, and Zoogonidae.

The Opcoelidae is the richest family with 15 species, including two species each of *Macvicaria*, *Neolebouria*, and *Pseudoplagioporus*, and at least four species of *Neochoanostoma*. The systematics of the family is complex and difficult (Cribb 2005). A study of the opcoelid fauna of the lethrinids of the Great Barrier Reef is in progress, and when complete will enable detailed taxonomic comparisons with the New Caledonian fauna. *Neolebouria* sp. A is a large, common species superficially resembling *Hamacreadium mutabile*, a cosmopolitan species in lutjanids. There have been several reports of *Hamacreadium* spp. from *Lethrinus* spp., including one of *H. mutabile* in *L. miniatus* from New Caledonia (Durio & Manter 1968b). In New Caledonian waters we have found *H. mutabile* only in *Lutjanus* spp.

The Hemiuridae has four species, including records of *Lecithochirium* sp. from three hosts. Two species, *Parahemiurus merus* and *Tubulovesicula angusticauda*, are cosmopolitan tropical and subtropical species, with low host-specificity. Similarly, *Elytrophalloides oatesi* has low host-specificity, but has a southern temperate and cold-water circum-polar distribution.

The Acanthocolpidae is represented by two species, including *Stephanostomum japonocassum*, a species originally described from serranids off New Caledonia (Durio & Manter 1969); interestingly, this species was found in several serranids and a single lethrinid, *L. miniatus*, all sharing a common environment, the external slope of the reef barrier, and was not found in any of the lethrinids from inside the lagoon (Bray & Justine 2011).

A single specimen of *Bivesicula* was recovered. As far as we are aware this is the first report of a member of this family from a lethrinid.

All zoogonid specimens recorded belong to *Zoogonus*. Durio & Manter (1968a) reported *Diptherostomum tropicum* from *Lethrinus* sp. off New Caledonia, but we have not recovered this species.

Members of the family Transversotrematidae occur under the scales, and can be collected only with special techniques (Cribb & Bray 2010); these techniques were applied only to a few individuals belonging to a few species of fish. However, it might be significant that several specimens of *Lethrinus* spp. investigated did not provide any transversotrematid, although they were found on two species of *Gymnocranius*. Hunter & Cribb (2010) have shown that transversotrematids are common in the Indo-Pacific region, and that there are many, as yet unrecognised, species. They reported species in several families including the Lethrinidae. On the Great Barrier Reef *L. atkinsoni* harbours a member of their Species Group A.

Cestoda Bothriocephalidea, Lecanicephalidea and Tetraphyllidea. For these three orders of cestodes, only larvae were found.

Bothriocephalideans were represented by a single case of a larva found in *L. miniatus*. No adult was found, although these cestodes are found in a few fish families in New Caledonia (Kuchta *et al.* 2009).

Tetraphyllideans were represented by small larvae within the lumen of the intestine, found in six host species. These larvae cannot be identified at the species level based on their morphology, but were kept in ethanol for future possible molecular identification, which is possible when a database established from identifiable adults is available (Jensen & Bullard 2010). It might be that lecanicephalideans or rhinebothriideans are included within certain of these records. A single specimen on the gills of *L. nebulosus* was differentiated as a lecanicephalidean larva.

With our cautious, minimizing approach, larvae of these three orders of cestodes are counted as a total of three taxa but likely represent a very high biodiversity, probably dozens of species, since sharks and rays are abundant in the same waters and harbour many species of adult tetraphyllideans and lecanicephalideans (Beveridge & Justine 2006; Justine 2010, and unpublished observations).

Cestoda Trypanorhyncha. Only larvae were found. Six species of larval trypanorhynch cestodes were identified at the species level, and two additional records could not be identified. As with adult tetraphyllideans, trypanorhynchs have adults in sharks (suborder Trypanoselachoida Olson *et al.*, 2010) and rays (suborder Trypanobatoida Olson *et al.*, 2010), but their larvae can usually be identified at the species level by the armature of the tentacles.

Trypanoselachoidans included five nominal species. *Callitetrarhynchus gracilis*, *Floriceps minacanthus* and *Pseudolacistorhynchus heroniensis* are three lacistorhynchid species which have been recorded in many

species of serranids in New Caledonia and whose main biological characteristic is apparently the lack of specificity of the larval stages (Justine *et al.*, 2010). Curiously, and probably of significance, the pseudotbothriid *Pseudotbothrium dipsacum* (Linton), also a widespread species in serranids, was not found in lethrinids perhaps hinting at differences in host diet.

Otobothrium parvum was recently described from adults from the shark *Triaenodon obesus* in New Caledonia (Beveridge & Justine 2007), and the finding of larvae in *L. rubrioperculatus* allows insight into the life cycle of the species.

Pseudogilquinia microbothria was recently redescribed from larvae found in serranids in New Caledonia and in lethrinids in Australia (Beveridge *et al.* 2007). The present finding of larvae in *L. miniatus* confirms that these two families are part of the life-cycle of this species in both locations.

Trypanobatoidea included one species, *Nybelinia goreensis*. The Tentaculariidae originated in rays and show evidences of several host switches to and from sharks (Olson *et al.* 2010). The adult of this species is known only from the shark *Sphyrna lewini* (Griffith & Smith) in Senegal, West Africa, and plerocercoids have been recorded from only four species of teleost fish, all in Indonesia (Palm 2004).

Finally, all trypanorhynchs found in lethrinids, whether belonging to the Trypanoselachoida or Trypanobatoidea, have their adults parasitic in sharks and are probably transmitted to their final host by predation.

The contrast in the larval trypanorhynch fauna between four lethrinid species which were extensively sampled, namely the small species *L. genivittatus*, the medium sized species *G. euanus* (both devoid of larval trypanorhynchs) and *L. rubrioperculatus* (1 species) and the large species *L. miniatus* (with four species) is striking. The life-cycle of trypanorhynchs involves a crustacean, one or several successive intermediate hosts, and a final elasmobranch host. It is likely that *L. miniatus* accumulates larvae from its prey, probably smaller teleosts. Interestingly, this species is also the single lethrinid in New Caledonia which is renowned for ciguatera poisoning (Carpenter & Allen 1989; Laboute & Grandperrin 2000), which results from the toxin ciguatoxin accumulated along the food chain and especially affects predators at the top of the food chain (Lehane & Lewis 2000; Lewis 2001). Parasitology thus confirms that *L. miniatus* is an apex predator, accumulating trypanorhynch cestodes and ciguatoxin. See below for a comment about trophic types in *L. miniatus* and other *Lethrinus* spp.

Nematoda. Nematodes recorded belonged to seven families, the Anisakidae, Camallanidae, Cucullanidae, Cystidicolidae, Gnathostomatidae, Philometridae and Trichosomoididae.

The Anisakidae is mainly represented by larvae, generally encapsulated on the surface of organs or free in the lumen of the digestive tract. No effort has been made to identify these larvae at the generic level, and identification at the species level on the basis of morphology is impossible. Justine *et al.* (2010) reported that these larvae were present in most serranids and they are known to show very low host specificity (Williams & Jones 1994). Adults are in piscivorous elasmobranch, teleosts, marine reptiles, birds and mammals (Anderson 2000; Moravec 1994; Williams & Jones 1994).

The Gnathostomatidae were found only as larvae, which show low specificity; adults are parasites of elasmobranchs (e.g. Moravec & Justine 2006).

The Camallanidae includes two species, one of which, *Procamallanus* (*Spirocamallanus*) *monotaxis* could be identified at the species level, and the Cucullanidae includes a single unidentified species of *Dichelyne*.

The Cystidicolidae includes often small and very thin nematodes which are difficult to collect. A single species, *Ascarophisnema tridentatum*, was found in *G. euanus*; subsequent re-identification of the fish showed that the nematode has also been described from *Gymnocranius* sp. C (recorded as JNC3055 in the original description, Moravec & Justine 2010); *G. euanus* is the type-host and *Gymnocranius* sp. C is an additional host.

The Philometridae are tissue-dwelling parasites, characterised by long conspicuous coloured females and very small males. A single species, *Philometra lethrini*, was found in the gonads of three species of lethrinids. Since gonads were not examined for all fish species, and also because philometrids are only apparent when the gonads are developed during the hot season, it is likely that other fish are infected but their parasites were

not recorded. No philometrids were found in the eyes and orbits, although several lethrins were specially investigated for them in these organs (Moravec & Justine 2005).

The Trichosomoididae are small tissue-dwelling nematodes, and their infection is sometimes detected only when the females are dead, by the presence of dark eggs in the tissues (Moravec 2001). Two species were found. *Huffmanella filamentosa* was found in the gills of *G. grandoculis*, and was described from eggs only. *H. longa* was found in the swim bladder of the same fish species, and is clearly differentiated by its egg morphology; in addition, a single female has been described and is apparently the longest trichosomoidid known, with a length of 20 mm. After the description of this species, re-identification of the specimens of *Gymnocranius* was performed, and it appeared that fish JNC2174, from which the holotype female was collected, was in fact a member of the newly described fish species *G. oblongus*; *G. oblongus* thus becomes the type-host, and *G. grandoculis* is an additional host for *H. longa*.

Acanthocephala and Hirudinea. We noted two records of Acanthocephala and one record of a leech. These could not be identified at the species level, and are certainly rare or exceptional parasites of the lethrins.

Microsporidia. Although this paper is limited to metazoans, we briefly report here two cases of microsporidian infections which were more visible than many metazoan parasites. Perfectly spherical cysts, up to 5–7 mm in diameter, were found on the surface of the abdominal organs of *L. genivittatus* and *L. atkinsoni*. Microscopical examination of the cyst contents showed numerous, typically microsporidian spores.

A numerical evaluation of parasite biodiversity in lethrins. Our results (Appendices 1 and 2) include a number of parasite identifications, but the level of taxonomic identification varies greatly. Table 1 was compiled by counting each parasitological finding (i.e. each line in Appendix 1) as a host-parasite combination (HPC). Table 1 details the number of HPCs found in each fish species, and indicates how many fish specimens were examined.

The number of HPCs is different from the actual number of different parasite species, for two reasons (a) a parasite species present in several hosts is counted as several HPCs; and (b) HPCs in Table 1 enumerate findings which range widely in systematic precision, and may designate, in a decreasing order of taxonomic precision:

- Species-level identified parasites (SLIPs); these have full binomial names, and we do not include ‘cf’ identifications within them.
- Species-level identified parasites which have not yet received a binomial (such as the numbered copepods *Hatschekia* sp. 12–16, the numbered capsalids, and the digeneans *Neolebouria* sp. A and sp. B). We are confident that these represent valid, independent species but a comparison of the presence of these species in other locations or in other fish will not be possible until the names are published.
- Parasite species identified at the generic level only, but which probably represent only a single species (examples: several digeneans, *Lamellodiscus* sp.);
- Parasite species identified at the generic level only, but for which we already know that they represent several species (example: the monogeneans *Haliotrema* spp. and *Encotyllabe* spp.);
- Parasite species identified at the family or higher level, for which we know that abundant biodiversity is hidden within this HPC. This includes unidentifiable larvae such as gnathiid isopods, anisakid nematodes, didymozoid digeneans and tetraphyllidean metacestodes. We estimate that these may represent a total of about 50–100 species.

Only species-level identified parasites with binomial (SLIPs) allow valid comparison between locations and fish. Other HPCs provide a wealth of information, but do not allow comparison: what is the significance of having two fish species sharing the presence of unidentified larvae of a group, if these larvae may actually belong to dozens of different species, with different final hosts and life-cycles?

TABLE 3. Parasite biodiversity in lethriniids in New Caledonia for each parasite group, and a comparison with serranids. HPCs, number of host-parasite combinations; SLIP-HPCs: number of species-level identified parasite – host parasite combinations (the same parasite species found in several hosts is counted several times); SLIPs: number of species-level identified parasites (the same parasite species found in different hosts is counted a single time); minimized number of taxa: an evaluation in which all unidentified taxa in a group are counted as a single species; indistinguishable larval taxa: larvae which cannot be identified by morphological analysis. Group data from Justine *et al.* (2010).

Parasitological results		Isop	Cope	Mono	Poly	Dige	Both	Tetr	Tryp	Nema	Other	Total	Source
Lethrinidae (17 species)													
Expressed as totals :													
HPCs	9	21	53	4	59	1	7	10	21	3	188		This paper, Table 1
SLIP-HPCs	0	11	25	0	27	0	0	8	10	0	81		This paper, Table 1
SLIPs	0	7	11	0	13	0	0	6	5	0	42		This paper, Appendix 2
Minimized number of taxa	1	16	23	1	27	1	2	8	10	2	91		This paper, Appendix 2
non-SLIP taxa	0	8	11	1	13	0	0	0	4	2	39		This paper, Appendix 2
Indistinguishable larval taxa (a)	1	1	0	0	1	1	2	2	1	0	9 (a)		This paper, Appendix 2
Expressed as mean per fish species:													
HPCs	0.53	1.24	3.12	0.24	3.47	0.06	0.41	0.59	1.24	0.18	11.06		
SLIPs	0.00	0.41	0.65	0.00	0.76	0.00	0.00	0.35	0.29	0.00	2.47		
Serranidae (28 species)													
Expressed as totals :													
HPCs	20	53	97	0	76	4	13	35	37	2	337		Justine <i>et al.</i> 2010, Table 1
SLIP-HPCs	7	18	44	0	35	1	0	31	8	0	144		Justine <i>et al.</i> 2010, Appendix 2
SLIPs	3	7	42	0	13	1	0	5	4	0	75		Justine <i>et al.</i> 2010, Appendix 2
Minimized number of taxa	5	19	56	0	28	3	1	8	12	2	134		Justine <i>et al.</i> 2010, Appendix 2
non-SLIP taxa	1	10	14	0	14	0	0	0	7	2	48		Justine <i>et al.</i> 2010, Appendix 2
Indistinguishable larval taxa (a)	1	2	0	0	1	2	1	3	1	0	11 (a)		Justine <i>et al.</i> 2010, Appendix 2
Expressed as mean per fish species:													
HPCs	0.71	1.89	3.46	0.00	2.71	0.14	0.46	1.25	1.32	0.07	12.04		
SLIPs	0.11	0.25	1.50	0.00	0.46	0.04	0.00	0.18	0.14	0.00	2.68		

(a) unidentified larvae (gnathiid isopods, caligid and pennellid copepods, didymozoid digeneans, all tetraphyllids, and anisakid nematodes) probably represent a number of additional species. Tetraphyllids in lethriniids include here the single record of a lecanicephalid larva.

Tables 3 and 4 provide numerical information on the number of parasites found in all groups of parasites in lethrinids of New Caledonia; they also provide a comparison with the serranids of New Caledonia, based on the results of Justine *et al.* (2010); this comparison will be discussed below.

TABLE 4. Parasite biodiversity in lethrinid species of New Caledonia with large samples, with a comparison with similar serranids. HPCs, number of host-parasite combinations; SLIPs: number of species-level identified parasites (the same parasite species found in different hosts is counted only once). Polyopisthocotylean monogeneans, tetraphyllideans, bothriocephalideans and lecanicephalideans cestodes, Acanthocephala, Hirudinea, and Turbellaria provided no SLIP for these fish species and are grouped as ‘others’. Serranids from Justine *et al.* (2010).

Fish Family and species		Isop	Cope	Monop	Dige	Tryp	Nema	Others	Total
Lethrinidae									
<i>Gymnocranius euanus</i>	SLIPs	0	2	2	4	0	1	0	9
<i>Lethrinus genivittatus</i>	SLIPs	0	0	0	2	1	2	0	5
<i>Lethrinus miniatus</i>	SLIPs	0	1	3	7	4	1	0	16
<i>Lethrinus rubrioperculatus</i>	SLIPs	0	2	1	3	2	0	0	8
Totals (4 species)	SLIPs	0	5	6	16	7	4	0	38
Totals (4 species)	HPCs	3	9	15	35	9	10	8	89
per fish species	SLIPs	0.00	1.25	1.50	4.00	1.75	1.00	0.00	9.50
	HPCs	0.75	2.25	3.75	8.75	2.25	2.50	2.00	22.25
Serranidae									
<i>Cephalopholis boenak</i>	SLIPs	1	0	0	1	2	0	0	4
<i>Cephalopholis urodeta</i>	SLIPs	0	0	1	2	2	0	0	5
<i>Epinephelus cyanopodus</i>	SLIPs	1	4	7	4	2	2	0	20
<i>Epinephelus fasciatus</i>	SLIPs	0	0	2	4	2	2	0	10
<i>Epinephelus maculatus</i>	SLIPs	0	2	10	7	0	0	0	19
<i>Epinephelus merra</i>	SLIPs	0	1	1	2	0	0	0	4
<i>Plectropomus leopardus</i>	SLIPs	2	3	3	1	3	0	0	12
Totals (7 species)	SLIPs	4	10	24	21	11	4	0	74
Totals (7 species)	HPCs	8	24	34	39	12	11	8	136
per fish species	SLIPs	0.57	1.43	3.43	3.00	1.57	0.57	0.00	10.57
	HPCs	1.14	3.43	4.86	5.57	1.71	1.57	1.14	19.43

Table 3 provides results for all parasite groups and all fish investigated in this study. The total number of HPCs was 188, and the number of SLIP-HPCs was 81. The minimized number of taxa (a cautious minimized evaluation in which all unidentified taxa in a group are counted as a single taxon) was 91, and the number of different parasite species identified at the species level was 42. There are eight indistinguishable larval taxa, which probably correspond to a high number (50–100?) of different species, but which cannot be differentiated on the basis of morphological studies.

Table 3 includes evaluations of these numbers as means per species of fish. The main result was that 11.06 HPCs were found for each lethrinid species, with 2.47 SLIPs (identified with binomial) per fish species.

Because our sample included several species of fish for which only a few specimens were investigated (Table 1), results in Table 3 are severely biased by undersampling, and these results probably provide an underestimate of the actual parasite biodiversity. In Table 4, we present only those lethrinid species for which the sample was greater than 30 (from Table 1): these are *G. euanus*, *L. genivittatus*, *L. miniatus* and *L. rubrioperculatus*. These four best-sampled fish species had a mean of 22.25 HPCs per fish species, and a

mean of 9.50 parasite species per fish species (this minimized number includes only SLIPs). These results included, in decreasing order of parasite biodiversity, the digeneans (4 species per fish), trypanorhynch cestodes (1.75), monopisthocotylean monogeneans (1.5), copepods (1.25), nematodes (1), and isopods (0). We emphasize the fact that these results are extremely minimized by including only taxa identified to species level; they reflect as much the quality – or lack – of detailed systematic knowledge of a group rather than the real biodiversity. However, such results allow a valid and precise comparison with other fish groups. A comparison with serranids is presented below.

Parasite biodiversity, size of hosts, and a prediction of total parasite biodiversity in lethrinids. It is known that the number of parasites varies with the host size. In Table 5, we compared the number of parasite species on a small subset of our results, limited to three host species with a significant sample size (at least $n > 30$); only members of *Lethrinus* were compared to avoid a phylogenetic effect by introducing a member of a different genus and subfamily. *L. genivittatus* is a small species, *L. rubrioperculatus* is of intermediate size, and *L. miniatus* is the second largest fish in the family. Sizes of fish were based on those actually recorded from our samples of fish examined for parasitology, not from literature data.

TABLE 5. Size of fish and number of parasites in three species of *Lethrinus* with significant sample size ($n > 30$).

Fish species	Fork length (mm)	Weight (g)	n for Length and Weight	n for Parasitology	Number of HPCs	Number of SLIP-HPCs
<i>L. genivittatus</i>	177 ± 18 (123–210)	95 ± 28 (29–159)	111	127	16	5
<i>L. rubrioperculatus</i>	285 ± 28 (225–330)	434 ± 129 (200–700)	53	97	20	8
<i>L. miniatus</i>	448 ± 63 (304–555)	1715 ± 692 (503–3000)	29	31	31	16

Linear regression curves (not shown) computed from these values were:

$$\begin{aligned} \text{Number of HPCs} &= 0.0091 \times \text{Weight} + 15.546 \quad (R^2 = 0.9963) \text{ and} \\ \text{Number of HPCs} &= 0.0563 \times \text{Fork Length} + 5.2482 \quad (R^2 = 0.9787) \end{aligned}$$

The high value of R^2 for the HPCs/Weight linear regression suggests that the number of parasites is highly correlated with the size of the fish, with large fish having more parasite species than small fish, as expected (Luque & Poulin 2007). Similar results were obtained for serranids in New Caledonia. For the larger lethrinids, numbers of HPCs greater than 30 may be expected.

In Table 6, we tried to predict the total number of parasite species present in all lethrinid species of New Caledonia. Lethrinids are bottom-feeders, and although several trophic types can be distinguished (Lo Galbo *et al.* 2002), we used size alone (based on lengths) as a predictor of parasite biodiversity, and we considered that the results obtained on three species of *Lethrinus* could be extrapolated to other taxa. For this purpose, we classified all species into three categories: small (length < 300 mm), medium (300–600 mm) and large (700–1000 mm), and we considered that small fish had 16 HPCs (as observed in *L. genivittatus*), medium fish had 22 HPCs (a mean between 20 and 23, observed in *L. rubrioperculatus* and *G. euanus*, respectively) and large fish had 31 HPCs (as observed in *L. miniatus*).

The total predicted HPCs for the lethrinids of New Caledonia is 635 (Table 6) compared with the 188 HPCs actually observed in 17 species of fish (Table 3). Our observed result thus represents 30% of the predicted HPCs for all lethrinids of New Caledonia. For all lethrinids of the World, the prediction is 911 HPCs (Table 6).

A prediction of the number of different parasite species, i.e. an evaluation of total parasite biodiversity is also possible from these data. Numbers of SLIPs observed allow us to evaluate the actual number of species present. In Table 6, we considered that small fish (such as *L. genivittatus*; observed SLIPs = 5) had only five parasite species, medium fish (such as *L. rubrioperculatus* and *G. euanus*; observed SLIPs = 8 and 10, respectively) had 10 species, and that large fish (such as *L. miniatus*, SLIPs = 16, with several additional well

differentiated species) had 20 species. These estimates are minimal, since about 50 species of parasites are found in *L. miniatus* (see below, Tables 9–10) but we must keep in mind that a number of parasite species are shared between host fish species.

TABLE 6. Prediction of parasite biodiversity for all lethrinids known in New Caledonia. The prediction is based on a classification of maximum total length (from Carpenter & Allen 1989) in three categories (small-medium-large) with predicted HPCs and predicted species of 16, 22 and 31, and 5, 10 and 20, respectively (see text). Bold: species with large samples.

Fish species	NC	Fork Length (observed)	Total Length (literature)	HPCs (observed)	SLIPs (observed)	Size Category	Predicted HPCs	Predicted species
<i>Lethrinus variegatus</i>	NC		200	7	2	small	16	5
<i>Lethrinus genivittatus</i>	NC	177	250	16	5	small	16	5
<i>Lethrinus ravus</i>	NC		250	5	1	small	16	5
<i>Gnathodentex aurolineatus</i>	NC		300	1	0	small	16	5
<i>Gymnocranius elongatus</i>	NC		350			small	16	5
<i>Gymnocranius frenatus</i>			350			small	16	5
<i>Lethrinus semicinctus</i>	NC		350			small	16	5
<i>Gymnocranius audleyi</i>	NC		400			medium	22	10
<i>Lethrinus borbonicus</i>			400			medium	22	10
<i>Lethrinus ornatus</i>			400			medium	22	10
<i>Lethrinus reticulatus</i>			400			medium	22	10
<i>Gymnocranius euanus</i>	NC	355	450	23	9	medium	22	10
<i>Gymnocranius microdon</i>			450			medium	22	10
<i>Gymnocranius oblongus</i>	NC		450	8	5	medium	22	10
<i>Lethrinus crocineus</i>			450			medium	22	10
<i>Lethrinus haemopterus</i>			450			medium	22	10
<i>Lethrinus atkinsoni</i>	NC		500	6	3	medium	22	10
<i>Lethrinus atlanticus</i>			500			medium	22	10
<i>Lethrinus erythropterus</i>			500			medium	22	10
<i>Lethrinus harak</i>	NC		500	12	3	medium	22	10
<i>Lethrinus lentjan</i>	NC		500	7	3	medium	22	10
<i>Lethrinus rubrioperculatus</i>	NC	285	500	20	8	medium	22	10
<i>Lethrinus enigmaticus</i>			550			medium	22	10
<i>Wattsia mossambica</i>	NC		550			medium	22	10
<i>Lethrinus laticaudis</i>	NC		560			medium	22	10
<i>Lethrinus obsoletus</i>	NC		600	5	2	large	31	20
<i>Lethrinus xanthochilus</i>	NC		600	4	1	large	31	20
<i>Monotaxis grandoculis</i>	NC		600			large	31	20
<i>Monotaxis heterodon</i>	NC		600			large	31	20
<i>Lethrinus amboinensis</i>			700			large	31	20
<i>Lethrinus erythracanthus</i>	NC		700			large	31	20
<i>Lethrinus conchyliatus</i>			760			large	31	20
<i>Gymnocranius grandoculis</i>	NC		800	22	11	large	31	20
<i>Gymnocranius</i> sp. B	NC		800	8	6	large	31	20

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TABLE 6. (continued)

Fish species	NC	Fork Length (observed)	Total Length (literature)	HPCs (observed)	SLIPs (observed)	Size Category	Predicted HPCs	Predicted species
<i>Gymnocranius</i> sp. C	NC		800	2	1	large	31	20
<i>Lethrinus nebulosus</i>	NC		800	11	5	large	31	20
<i>Lethrinus miniatus</i>	NC	448	900	31	16	large	31	20
<i>Lethrinus olivaceus</i>	NC		1000			large	31	20
Total	NC			188	81			
Predicted total, NC (26 species)							635	340
Predicted total, World (38 species)							911	475
Predicted mean per fish, NC							24.42	13.07
Predicted mean per fish (World)							23.97	12.50

Our prediction therefore is of 340 parasite species for the lethrinids of New Caledonia (Table 6). Our results of 42 parasites identified at the species level (Table 3) thus represent 12.3 % of the total number of parasite species predicted in lethrinids in New Caledonia. For all lethrinids in the world, our prediction is 475 parasite species.

For serranids off New Caledonia, Justine *et al.* (2010) reported a total of 63 parasites identified at the species level and a prediction of 410 parasite species: the ratio of known parasite species was thus 15.3%. This ratio is similar to that computed for the lethrinids, and provides a pessimistic interpretation of the completeness of our results: 85–90% of the parasites of these two fish families are still unrecorded, or unnamed.

Failure of lethrinid trophic types to predict parasite fauna. Lo Galbo *et al.* (2002) studied the trophic types in *Lethrinus* spp. They explained that all *Lethrinus* spp. are demersal feeders with three distinct trophic modes. The first group consists of low-bodied species with conical teeth, which are stalking predators that mostly feed on mobile prey such as fish and crustaceans; this group includes *L. rubrioperculatus* and *L. genivittatus* (only the species we studied for parasitology are cited). The second group consists of high-bodied species with molariform teeth, which consume slow moving invertebrates, and can process both hard and soft-shelled prey such as molluscs, sea urchins and some crustaceans; this group includes *L. atkinsoni*, *L. lentjan*, *L. nebulosus* and *L. harak*. The third group consists of high-bodied species with conical teeth, which consume slow moving invertebrates and cannot process large hard-shelled invertebrates; this group includes *L. miniatus*.

Can we expect to detect differences in parasite fauna between these three trophic types? Species of *Lethrinus* with a large sample size in our study included *L. genivittatus* and *L. rubrioperculatus* (first group) and *L. miniatus* (third group). The diet of *L. genivittatus*, investigated in New Caledonia on the same individuals which were examined for parasites, included polychaetes, echinoderms, bryozoans and foraminiferans, with important individual variations, but not fish (Debenay *et al.* 2010). Members of the first group should display parasitological evidence of fish consumption, such as the presence of cryptogonimid digeneans, whose life-cycle includes a small fish as second intermediate host, and a higher abundance of trypanorhynch larvae, which involves a small fish as paratenic hosts and accumulate through the food chain. No cryptogonimid was observed in any lethrinid, probably for phylogenetic reasons (this family of digeneans has not invaded the lethrinids, but is abundant in lutjanids (Miller & Cribb 2008) and nemipterids, including those off New Caledonia (Miller *et al.* 2009)). For trypanorhynch larvae, we observed exactly the opposite of what was predicted from the trophic types, with *L. miniatus* having abundant larvae, in contrast to *L.*

genivittatus totally devoid of trypanorhynchs and *L. rubrioperculatus* with a single species. For trypanorhynchs, it might be simply that the different sizes of fish completely obscured the trophic types, with *L. miniatus*, a bigger species more likely to eat fish than *L. genivittatus*, a small species. Clearly, the trophic types of Lo Galbo *et al.* (2002) are not good predictors of parasite fauna acquired through diet.

Parasite biodiversity in lethrinids compared with serranids. In Table 7, we compared our results for the lethrinids (present study) and the serranids (Justine *et al.* 2010) of New Caledonia. When data for all fish investigated were compared, results for serranids were almost twice those for lethrinids, with more numerous HPCs (337 vs 188, 179% higher), and different parasite numbers (SLIPs = 75 vs 42, 179% higher). However, results on serranids were from more fish species (28 vs 17, 165%) and more sampled fish individuals (540 vs 423, 128%).

TABLE 7. Comparison of parasite biodiversity between groupers and lethrinids in New Caledonia. HPCs, number of host-parasite combinations; SLIPs: number of species-level identified parasites (the same parasite species found in different hosts is counted only once). Grouper data from Justine *et al.* (2010).

Fish Group and data set	Species	Fish	HPCs	HPCs / fish species	SLIPs	SLIPs / fish species
All data including poorly sampled species						
Emperors and Emperor Bream (Lethrinidae)	17	423	188	11.06	42	2.47
Groupers (Epinephelinae)	28	540	337	12.04	75	2.68
Selection of best-sampled species						
Emperors and Emperor Bream (Lethrinidae)	4	329	89	22.25	38	9.50
Groupers (Epinephelinae)	7	398	136	19.43	74	10.57

When these raw results were expressed as HPCs per fish species (Table 7), the results were very similar in both families. The number of HPCs per fish species was slightly higher for serranids (12.04 vs 11.06, 109%), as was the number of SLIPs per fish species (2.68 vs 2.47, 109%).

Because certain fish species were poorly sampled in both families, we compared a subset of these data, for which we kept only the best sampled fish species ($n > 30$ for lethrinids and $n > 25$ for serranids). These results included four lethrinids and seven serranids (listed in Table 4). The number of HPCs was higher for the seven serranids than for the four lethrinids (136 vs 89) as was the number of SLIPs (74 vs 38). When expressed as means per species, the results were very similar: 19.43 HPCs per fish in serranids (vs 22.25 in lethrinids, 87%) and 10.57 SLIPs per fish in serranids (vs 9.50 in lethrinids, 111%). These results suggest that *parasite biodiversity is of similar magnitude in both fish families off New Caledonia*.

Table 4 also provides results for all parasite groups in these well-sampled fish from both families. The comparisons of results in both families, expressed as number of SLIPs per fish species, are contrasted. Results were similar in copepods (1.43 vs 1.25) and trypanorhynch cestodes (1.57 vs 1.75). They were slightly higher for digeneans in lethrinids (4.00 vs 3.00), suggesting somewhat higher digenean biodiversity in lethrinids, but it might be that this difference also reflects the fact that many digeneans from serranids could not be identified at the species level; a similar difference was found in nematodes (1.00 vs 0.57). Results are lower for isopods in lethrinids (0 vs 0.57), because no adult isopod was found in lethrinids. The most striking difference was found for monopisthocotylean monogeneans, with 3.43 monogeneans identified at the species level per fish in serranids compared to 1.50 in lethrinids (228%). Capsalids and ancyrocephalids were poorly identified in both fish families; as stated earlier, capsalids from the head of lethrinids are poorly studied but may represent a genus or genera unique to this fish family, but their level of host specificity is unknown. The diplectanids are responsible for this difference. Diplectanids from serranids show extremely strict host specificity, with most species of *Pseudorhabdosynochus*, the major genus in term of species number, each limited to a single species of grouper (Justine 2007b; Justine *et al.* 2010), while diplectanids of lethrinids (members of *Calydiscooides* in *Lethrinus* and *Lamellodiscus* in *Gymnocranius*) show a wider host specificity and are often found in 3–5 host species (Justine 2007c; Justine & Briand 2010; Rascalou & Justine 2007).

An attempt at biogeographical comparison. Justine *et al.* (2010) emphasized that a comparison of the biodiversity of parasites in groupers from New Caledonia with that from other locations was almost impossible because of the lack of comparable general lists of parasites for coral reef fish. Table 8 lists general surveys of fish parasites available for the Indo-Pacific. As for the serranids, the only general publication which can be used for a comparison for parasites of lethrinids is the general list of Lester & Sewell (1989) for Heron Island on the Great Barrier Reef, Queensland. This work has only three lethrinid species in common with our list: *L. miniatus* (as *L. chrysostomus*), *L. atkinsoni* (as *L. mahsena*) and *L. nebulosus*. Only the list of parasites for *L. miniatus* provides significant information and can be valuably compared with our results in New Caledonia. In addition, another, more recent paper, listed only gill and head parasites of *L. miniatus* at three localities on the Great Barrier Reef, including Heron Island (Rohde *et al.* 1994). The book on trypanorhynchs of Palm (2004) provided general compilation lists which are useful for biogeographical comparisons (see below).

TABLE 8. Available references on the parasites of lethrinids in the Indo-Pacific Region.

Reference	Parasite group	Locality	Number of lethrinid species mentioned	Number of lethrinid species in common with the present study	Number of parasites mentioned in the fish species in common
Zhang <i>et al.</i> 2003	Monogeneans	China	2	1	1
Rigby <i>et al.</i> 1999	all	French Polynesia	5	1	1
Yang 2007	Cestodes	China	0	0	0
Arthur & Te 2006	all	Viet Nam	1	0	0
Arthur & Lumanlan-Mayo 1997	all	Philippines	3	1	1
Arthur & Ahmed 2002	all	Bangladesh	0	0	0
Yamaguti 1968	Monogeneans	Hawaii	1	0	0
Beumer <i>et al.</i> 1983	all	Australia	4	1	11
Al Kawari <i>et al.</i> 1996	Digeneans	Arabian Gulf	2	2	10 (genera only)
Saoud & Ramadan 1983	Digeneans	Arabian Gulf	4	2	13 (genera only)
Palm 2004	Trypanorhynch cestodes	all	9	6	12 (Table 12)
Lester & Sewell 1989	all	Heron Island, Queensland, Australia	3	1	26 (Table 10)
Rohde <i>et al.</i> 1994	All, head and gills only	3 localities, Great Barrier Reef, Australia	1	1	22 (Table 10)

Table 9 lists all records (host-parasite combinations) from *L. miniatus* in Lester & Sewell's compilation and in the work of Rohde *et al.*, and our results in New Caledonia. Table 10 is an attempt to compare results at both locations in term of parasite biodiversity. At Heron Island, 40 HPCs were recorded (26 by Lester & Sewell, 22 by Rohde *et al.*), compared to 28 HPCs in New Caledonia, with a total of 64 HPCs for this fish species. We tried to 'guess' the number of different parasite species involved by supposing equivalences between various records, but always with a minimizing approach; for example, we considered that there are a total of three ancycrocephalids, five capsalids and four diplectanids. The result (Table 10) is a total of 52 different parasite species present in *L. miniatus*, with the certainty that this number would be increased by identification of the larvae of gnathiid isopods, tetraphyllid cestodes and anisakid nematodes. Among all 64 HPCs, only six parasite species identified at the species level in both locations were shared (Table 9): these are

three monopisthocotyleans (the pharyngeal teeth capsalid *Encotyllabe caballeroi* and the gill diplectanids *Calydiscooides australis* and *C. gussevi*) and three intestinal digeneans (the acanthocolpid *Stephanostomum aaravi* and the opecoelids *Macvicaria macassarensis* and *Pseudoplagiopus interruptus*).

TABLE 9. *Lethrinus miniatus*: comparison of its parasitic fauna at Heron Island, Queensland, Australia (HI) from data from Lester & Sewell (1989) (LS) and Rohde *et al.* (1994) (R) (Australia), and New Caledonia (NC) (present study).

Parasite: Group	Parasite: Family	Parasite: Name	HI (LS)	HI (R)	NC	Shared
Isopoda	Aegidae	<i>Aega cyclops</i>	+			
	Aegidae	<i>Aega lethrina</i>	+	+		
	Gnathiidae	<i>Praniza larvae</i> (as <i>Gnathia</i> sp. in R)		+	+	
	Corallanidae	<i>Argathona macronema</i>		+		
Copepoda	Philichthyidae	<i>Colobomatus icopaius</i>	+	+		
	Bomolochidae	unidentified	+	+		
	Dissonidae	<i>Dissonus excavatus</i>			+	
	Caligidae	unidentified	+			
	Caligidae	<i>Lepeophtheirus</i> sp.		+		
	Lernaeopodidae	<i>Neobrachiella</i> sp.		+		
	Caligidae	<i>Caligus</i> sp.		+		
	Hatschekiidae	<i>Hatschekia</i> cf. <i>elegans</i>			+	
	Hatschekiidae	<i>Hatschekia elegans</i>		+		
	Hatschekiidae	<i>Hatschekia</i> n. sp. 18			+	
	Hatschekiidae	unidentified	+			
Monogenea Monopisthocotylea	Ancyrocephalidae	<i>Haliotrema chrysostomi</i>	+	+		
	Ancyrocephalidae	<i>Haliotrema</i> sp.			+	
	Ancyrocephalidae	sp.	+			
	Ancyrocephalidae	<i>Haliotrema fleti</i>		+		
	Ancyrocephalidae	<i>Haliotrema lethrini</i>		+		
	Capsalidae	<i>Encotyllabe caballeroi</i>	+	+	+	shared
	Capsalidae	unidentified	+			
	Capsalidae	<i>Benedeniinae</i> sp. A		+		
	Capsalidae	<i>Benedeniinae</i> sp. B		+		
	Capsalidae	<i>Benedeniinae</i> sp. C		+		
	Capsalidae	<i>Benedeniinae</i> sp. E		+		
	Capsalidae	<i>Capsalidae</i> sp. 10			+	
	Capsalidae	<i>Capsalidae</i> sp. 16			+	
	Diplectanidae	<i>Calydiscooides australis</i>	+	+	+	shared
	Diplectanidae	<i>Calydiscooides difficilis</i>	+	+		
	Diplectanidae	<i>Calydiscooides gussevi</i>	+	+	+	shared
	Diplectanidae	<i>Lamellodiscus</i> sp.	+			
	Diplectanidae	<i>Protolamellodiscus</i> sp.		+		
Digenea	Acanthocolpidae	<i>Stephanostomum aaravi</i> *	+		+	shared
	Acanthocolpidae	<i>Stephanostomum japonocasum</i>			+	

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TABLE 9. (continued)

Parasite: Group	Parasite: Family	Parasite: Name	HI (LS)	HI (R)	NC	Shared
Cest. Bothriocephalidea	Acanthocolpidae	<i>Stephanostomum pagrosomi</i> *	+			
	Didymozoidae	Unidentified (adult ?)	+			
	Didymozoidae	Unidentified adult			+	
	Hemiuridae	<i>Elytrophalloides oatesi</i>			+	
	Hemiuridae	<i>Parahemiurus merus</i>			+	
	Hemiuridae	<i>Lecithochirium</i> sp.			+	
	Microscaphidiidae	<i>Hexangium</i> sp. <i>metacercariae</i>	+			
	Opecoelidae	<i>Fairfaxia lethrini</i>	+			
	Opecoelidae	<i>Neolebouria</i> sp. A			+	
	Opecoelidae	<i>Macvicaria heronensis</i>	+			
	Opecoelidae	<i>Macvicaria macassarensis</i>	+		+	shared
	Opecoelidae	<i>Orthodena tropica</i>	+			
	Opecoelidae	<i>Pseudoplagioporos interruptus</i>	+		+	shared
	Opecoelidae	<i>Pseudoplagioporos lethrini</i>			+	
	Unidentified	Unidentified			+	
	Unidentified	Unidentified			+	
	Unidentified	Unidentified			+	
	Unidentified	Unidentified			+	
	Unidentified	Unidentified			+	
	Unidentified	Unidentified			+	
Nematoda	Anisakidae	<i>Hysterothylacium</i> type 3	+			
	Anisakidae	unidentified	+			
	Anisakidae	<i>Raphidascaris</i> sp.			+	
	Anisakidae	Unidentified larvae			+	
	Cucullanidae	<i>Cucullanus</i> sp.	+			
	Cucullanidae	<i>Dichelyne</i> sp.			+	
	Philometridae	<i>Philometra lethrini</i>			+	
	Unidentified	Unidentified			+	
	Piscicolidae	<i>Trachelobdella lubrica</i>		+		

* As *Stephanostomum* sp. 1 and sp. 2 in Lester & Sewell; species identification in Bray & Cribb 2003.

It is disappointing to see that comparative lists with 64 HPCs for a single fish species, which contain abundant taxonomic information representing considerable sampling and identification work, can only provide the limited information that six parasite species are common between two localities. The main reasons for this are probably the insufficient number of parasites identified at the species level, and differences in sample intensity (digeneans and trypanorhynch cestodes being clearly less well sampled at Heron Island). However, this illustrates fully the difficulty – almost the impossibility – of attempting biogeographical comparisons of coral reef parasites on the basis of available records. For serranids, Justine *et al.* (2010) have already complained that, in spite of 146 precise species identifications in New Caledonia, only six parasites identified at the species level could be found in common between Heron Island and New Caledonian, belonging to a total of only three fish species.

TABLE 10. *Lethrinus miniatus*: Host-parasite combinations recorded off Heron Island (HI) and New Caledonia (NC) (present study), and species-level identified parasites (SLIPs) shared by both locations. The number of different species was ‘estimated’ by hypothesizing similarities between different records and was kept to a minimum. + indicates cases in which the identification of larvae would certainly increase these numbers (gnathiid isopods, tetraphyllidean cestodes and anisakid nematodes).

Group	Total HPCs	HI HPCs	NC HPCs	Number of different species	SLIPs in common
Isopoda	4	4	1	4+	0
Copepoda	11	8	3	8	0
Monopisthocotylea	18	13	6	13	3
Digenea	16	9	10	15	3
Cestoda Bothriocephalidea	1	0	1	1	0
Cestoda Tetraphyllidea	1	0	1	1+	0
Cestoda Trypanorhyncha	4	0	4	4	0
Nematoda	7	3	4	4+	0
Acanthocephala	1	0	1	1	0
Hirudinea	1	1	0	1	0
Total	64	38	31	52+	6

TABLE 11. Trypanorhynch cestode larvae in lethrinids: comparison between the compilation list of Palm (2004) and the present study; only fish species shared by both studies are mentioned. HI, Heron Island; NC, New Caledonia. A single trypanorhynch species is shared at both sites (bold).

Fish/ Parasite: Family	Parasite: Name	Palm	Present study
<i>Lethrinus atkinsoni</i>			
Lacistorhynchidae	<i>Pseudogilquinia pillersi</i> (Southwell, 1929)	HI, Australia	
<i>Lethrinus lentjan</i>			
Tentaculariidae	<i>Heteronybelinia elongata</i> (Shah & Bilqees, 1979)	Arabian Gulf	
Lacistorhynchidae	<i>Floriceps</i> sp.	Arabian Gulf	
<i>Lethrinus miniatus</i> *			
Lacistorhynchidae	<i>Floriceps minacanthus</i>	HI, Australia	NC
Lacistorhynchidae	<i>Pseudogilquinia</i> sp.	HI, Australia	
Lacistorhynchidae	<i>Callitetrarhynchus gracilis</i>		NC
Lacistorhynchidae	<i>Pseudogilquinia microbothria</i>		NC
Lacistorhynchidae	<i>Pseudolacistorhynchus heroniensis</i>		NC
<i>Lethrinus nebulosus</i>			
Rhopalothylacidae	<i>Pintneriella musculicola</i> Yamaguti, 1934	Arabian Gulf	
Lacistorhynchidae	<i>Pseudolacistorhynchus heroniensis</i>	HI, Australia	
Lacistorhynchidae	<i>Callitetrarhynchus speciosus</i> (Linton, 1897)	Arabian Gulf	
Lacistorhynchidae	<i>Callitetrarhynchus</i> sp.	Arabian Gulf	
Lacistorhynchidae	<i>Floriceps</i> sp.	Arabian Gulf	

* ‘*L. chrysostomus*’ records included within *L. miniatus*.

Palm (2004), from a compilation of the literature (Hassan *et al.* 2002) and unpublished data, produced a list of hosts for trypanorhynch cestodes. In Table 11, we report all results on trypanorhynch larvae from lethrinids from Palm (2004) and the present work, limited to the four fish species which were shared by both

studies (*L. atkinsoni*, *L. lentjan*, *L. miniatus* and *L. nebulosus*). Palm's list provides 13 HPCs and 11 species including eight which were identified at the species level. Our list includes four HPCs, all identified to the species level, for only one of the fish species, *L. miniatus*. Incomplete sampling (especially for *L. nebulosus* in our study) is probably responsible for the lack of convergence between the two lists; a single trypanorhynch cestode, *Floriceps minacanthus*, was found in both lists.

Predictions for general biodiversity of parasites in coral reef fish. From results on serranids only (Justine *et al.* 2010), a total biodiversity of about 10 different parasite species per fish species was predicted for the 1,700 fish species of the Lagoon of New Caledonia. In this study, on the basis of a somewhat more precise evaluation based on the size of various host species, we predict a total of 340 parasite species for the lethrinids of New Caledonia, i.e. *a mean of 13 parasite species per lethrinid species*. Moreover, for all predictions, we have erred on the side of caution and all numbers have always been minimized and therefore likely greatly underestimate parasite biodiversity on lethrinids. The present study confirms that parasite biodiversity in coral reef fish is huge; unfortunately, it also confirms that the current knowledge of this biodiversity is extremely poor.

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Appendix 1. Host-parasite list (17 fish species)

For brevity, all references are numbered according to this list: [0] This paper; [1] Boxshall & El-Rashidy 2009; [2] Bray & Justine 2008; [3] Bray & Justine 2011; [4] Justine 2004 ; [5] Justine 2007a ; [6] Justine 2007c; [7] Justine & Briand 2010; [8] Moravec & Justine 2008; [9] Moravec & Justine 2009; [10] Moravec & Justine 2010; [11] Moravec *et al.* 2006 ; [12] Perkins 2010; [13] Rascalou & Justine 2007.

Monotaxinae

Gnathodentex aureolineatus (Lacépède)

Mono: Dipl: *Lamellodiscus* sp. of Justine & Briand, 2010 (gills) [7]

Remarks: 3 specimens examined (3 for gills).

HPCs: 1; SLIP-HPCs: 0.

Gymnocranius euanus (Günther)

Cope: Cali: *Caligus novocaledonicus* Kabata, 1968 (gills) [0] (NHR)

Cope: Hats: *Hatschekia* n. sp. 12 (gills) [0]

Cope: Hats: *Hatschekia rotundigenitalis* Yamaguti, 1939 (gills) [0] (NHR)

Cope: Lerp: *Parabrachiella* sp. 1 (pharyngeal teeth) [0]

Mono: Caps: *Encotyllabe* sp. 3 of Perkins, 2010 (pharyngeal teeth) [12]

Mono: Caps: unidentified adult (body) [0]

Mono: Dipl: *Lamellodiscus magnicornis* Justine & Briand, 2010 (gills) [7]

Mono: Dipl: *Lamellodiscus parvicornis* Justine & Briand, 2010 (gills) [7]

Poly: Micr: unidentified immature (gills) [6]

Dige: Didy: unidentified adult (stomach wall) [0]

Dige: Didy: unidentified larvae (digestive tract) [0]

Dige: Hemi: *Elytrophalloides oatesi* (Leiper & Atkinson, 1914) Szidat & Graefe, 1967 (digestive tract) [0] (NHR)

Dige: Hemi: *Tubulovesicula angusticauda* (Nicoll, 1915) Yamaguti, 1934 (digestive tract) [0]

Dige: Opec: *Neochoanostoma avidabira* Bray & Cribb, 1989 (digestive tract) [0] (NHR)

Dige: Opec: *Neochoanostoma* sp. A (digestive tract) [0]

Dige: Opec: *Neochoanostoma* sp. B (digestive tract) [0]

Dige: Opec: *Propychnadenoides philippinensis* Fischthal & Kuntz, 1964 (digestive tract) [0] (NHR)

Dige: Tran: *Transversotrema* sp. (scales)

Dige: Zoog: *Zoogonus* sp. (digestive tract) [0]

Tetr: Unid: larvae (digestive tract) [0]

Tryp: Unid: larvae (digestive tract) [0]

Nema: Anis: unidentified larvae (digestive tract) [0]

Nema: Cyst: *Ascarophisnema tridentatum* Moravec & Justine, 2010 (digestive tract) [10]

Remarks: 74 specimens examined (38 for gills, 60 for abdominal organs).

HPCs: 23; SLIP-HPCs: 9.

Gymnocranius grandoculis (Valenciennes)

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Cope: Cali: *Caligus* n. sp. 1 (gills) [0]

Cope: Cali: *Caligus novocaledonicus* (gills) [0] (NHR)

Cope: Hats: *Hatschekia megacephala* Kabata, 1991 (gills) [0] (NHR)

Cope: Hats: *Hatschekia* n. sp. 14 (gills) [0]

Cope: Hats: *Hatschekia rotundigenitalis* (gills) [0] (NHR)

Mono: Caps: Capsalidae sp. 8 of Perkins, 2010 (branchiostegal membranes) [12]

Mono: Caps: *Encotyllabe* sp. 2 of Perkins, 2010 (pharyngeal teeth) [12]

Mono: Dipl: *Lamellodiscus magnicornis* (gills) [7]
Mono: Dipl: *Lamellodiscus parvicornis* (gills) [7]
Mono: Dipl: *Lamellodiscus tubulicornis* Justine & Briand, 2010 (gills) [7]

Poly: Micr: unidentified immature (gills) [6]

Dige: Didy: unidentified larvae (gills) [0]
Dige: Didy: unidentified adult (stomach wall) [0]
Dige: Opec: *Neochoanostoma avidabira* (digestive tract) [0] (NHR)
Dige: Opec: *Neochoanostoma* sp. (digestive tract) [0]
Dige: Opec: *Propycnadenoides philippinensis* (digestive tract) [0] (NHR)
Dige: Tran: *Transversotrema* sp. (scales) [0]

Tryp: Laci: *Pseudolacistorhynchus heroniensis* (Sakanari, 1989) Palm, 2004 (abdominal cavity) [0] (NHR)

Nema: Anis: unidentified larvae (digestive tract) [0]
Nema: Tric: *Huffmanella filamentosa* Justine, 2004 (gills) [4]
Nema: Tric: *Huffmanella longa* Justine, 2007 (swim bladder) [5]

Remarks: 15 specimens examined (15 for gills, 11 for abdominal organs).
HPCs: 22; SLIP-HPCs: 11.

***Gymnocranius oblongus* Borsa, Béarez & Chen, 2010**

Synonym : *Gymnocranius* sp. A of Borsa in Justine & Briand, 2010

Cope: Cali: *Caligus novocaledonicus* (gills) [0] (NHR)

Mono: Caps: *Encotyllabe* sp. (pharyngeal teeth) [0]
Mono: Dipl: *Lamellodiscus magnicornis* (gills) [7]

Poly: Micr: unidentified immature (gills) [0]

Dige: Didy: unidentified adult (stomach wall) [0]
Dige: Opec: *Neochoanostoma avidabira* (digestive tract) [0] (NHR)
Dige: Opec: *Propycnadenoides philippinensis* (digestive tract) [0] (NHR)

Nema: Tric : *Huffmanella longa* (swim bladder) [0] (NHR)

Remarks: 4 specimens examined (4 for gills, 2 for abdominal organs).
The record of *H. longa* was attributed only to *G. grandoculis* prior to the differentiation of this fish species [5]
HPCs: 8; SLIP-HPCs: 5.

***Gymnocranius* sp. B of Borsa in Justine & Briand, 2010**

Mono: Caps: *Encotyllabe* sp. (pharyngeal teeth) [0]
Mono: Dipl: *Lamellodiscus magnicornis* (gills) [7]
Mono: Dipl: *Lamellodiscus parvicornis* (gills) [7]
Mono: Dipl: *Lamellodiscus tubulicornis* (gills) [7]

Dige: Opec: *Neochoanostoma avidabira* (digestive tract) [0] (NHR)
Dige: Opec: *Neochoanostoma bariadiva* Bray & Cribb, 1989 (digestive tract) [0] (NHR)
Dige: Opec: *Propycnadenoides philippinensis* (digestive tract) [0] (NHR)

Nema: Anis: unidentified larvae (digestive tract) [0]

Remarks: 4 specimens examined (3 for gills, 2 for abdominal organs).
HPCs: 8; SLIP-HPCs: 6.

***Gymnocranius* sp. C of Borsa, Béarez & Chen, 2010**

Dige: Opec: *Neochoanostoma* sp. (digestive tract) [0]

Nema: Cyst: *Ascarophisnema tridentatum* (digestive tract) [10] (NHR)

Remarks: 2 specimens examined (1 for gills, 2 for abdominal organs).
The record of *A. tridentatum* was attributed only to *G. euanus* prior to differentiation of this fish species.
HPCs: 2; SLIP-HPCs: 1.

Lethrininae

Lethrinus atkinsoni Seale

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Mono: Dipl: *Calydiscooides rohdei* Oliver, 1984 (gills) [6]

Dige: Opec: *Macvicaria macassarensis* (Yamaguti, 1953) Bray & Cribb, 1989 (digestive tract) [0] (NHR)

Dige: Opec: *Neolebouria* sp. A (digestive tract) [0]

Dige: Zoog: *Zoogonus pagrosomi* Yamaguti, 1939 (digestive tract) [2]

Tetr: Unid: larvae (digestive tract) [0]

Remarks: 24 specimens examined (21 for gills, 14 for abdominal organs).

HPCs: 6; SLIP-HPCs: 3.

Lethrinus genivittatus Valenciennes

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Mono: Caps: unidentified (body) [0]

Dige: Bive: *Bivesicula* sp. (digestive tract) [0]

Dige: Hemi: *Lecithochirium* sp. (digestive tract) [0]

Dige: Opec: *Macvicaria* sp. (digestive tract) [0]

Dige: Opec: *Neochaoanostoma* sp. (digestive tract) [0]

Dige: Opec: *Neolebouria* sp. B (digestive tract) [0]

Dige: Opec: *Orthodena tropica* Durio & Manter, 1968 (digestive tract) [0] (NHR)

Dige: Zoog: *Zoogonus pagrosomi* (digestive tract) [2]

Tetr: Unid: larvae (digestive tract) [0]

Tryp: Eute: unidentified larva (abdominal cavity) [0]

Tryp: Tent: *Nybelinia goreensis* Dollfus, 1960 larva (abdominal cavity) [0] (NHR)

Nema: Anis: *Raphidascaris* sp. (digestive tract) [0]

Nema: Cama: *Procamallanus (Spirocamallanus) monotaxis* (Olsen, 1952) (digestive tract) [0] (NHR)

Nema: Gnto: *Echinocephalus* sp. larva (digestive tract) [0]

Nema: Phil: *Philometra lethrini* Moravec & Justine, 2008 (gonads) [8]

Remarks: 127 specimens examined (46 for gills, 118 for abdominal organs).

HPCs: 16; SLIP-HPCs: 5.

Lethrinus harak (Forsskål)

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Cope: Hats: *Hatschekia* n. sp. 15 (gills) [0]

Mono: Ancy: *Haliotrema* sp. 1 (gills) [13]

Mono: Ancy: *Haliotrema* sp. 2 (gills) [13]

Mono: Ancy: *Haliotrema* sp. 3 (gills) [13]

Mono: Caps: *Encotyllabe* sp. (pharyngeal teeth) [0]

Mono: Dipl: *Calydiscooides difficilis* (Yamaguti, 1953) Young, 1969 (gills) [13]

Mono: Dipl: *Calydiscooides duplicostatus* (Yamaguti, 1953) Young, 1969 (gills) [13]

Mono: Dipl: *Calydiscooides terpsichore* Rascalou & Justine, 2007 (gills) [13]

Dige: Didy: unidentified adult (gills) [13]

Dige: Opec: *Orthodena* sp. (digestive tract) [13]

Hiru: unidentified (gills) [13]

Remarks: 8 specimens examined (8 for gills, 2 for abdominal organs).
HPCs: 12; SLIP-HPCs: 3.

***Lethrinus lentjan* (Lacépède)**

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Mono: Ancy: *Haliotrema* sp. (gills) [13]

Mono: Dipl: *Calydiscoides difficilis* (gills) [13]

Mono: Dipl: *Calydiscoides duplicostatus* (gills) [13]

Dige: Opec: *Neolebouria* sp. B (digestive tract) [0]

Dige: Opec: *Orthodena tropica* (digestive tract) [0] (NHR)

Nema: Anis: unidentified larvae (digestive tract) [0]

Remarks: 9 specimens examined (9 for gills, 7 for abdominal organs).
HPCs: 7; SLIP-HPCs: 3.

***Lethrinus miniatus* (Forster)**

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Cope: Cali: *Dissonus excavatus* Boxshall, Lin, Ho, Ohtsuka, Maran & Justine, 2008 (gills) [0] (NHR)

Cope: Hats: *Hatschekia* cf. *elegans* Kabata, 1991 (gills) [0]

Cope: Hats: *Hatschekia* n. sp. 16 (gills) [0]

Mono: Ancy: *Haliotrema* sp. (gills) [0]

Mono: Caps: Capsalidae sp. 10 of Perkins, 2010 (skin) [12]

Mono: Caps: Capsalidae sp. 16 of Perkins, 2010 (body washing) [12]

Mono: Caps: *Encotyllabe caballeroi* Velasquez, 1977 (pharyngeal teeth) [12]

Mono: Dipl: *Calydiscoides australis* Young, 1969 (gills) [6]

Mono: Dipl: *Calydiscoides gussevi* Oliver, 1984 (gills) [6]

Dige: Acan: *Stephanostomum aaravi* Bray & Cribb, 2003 (digestive tract) [3]

Dige: Acan: *Stephanostomum japonocasum* Durio & Manter, 1969 (digestive tract) [3]

Dige: Didy: unidentified adult (gills) [0]

Dige: Hemi: *Elytrophalloides oatesi* (digestive tract) [0] (NHR)

Dige: Hemi: *Lecithochirium* sp. (digestive tract) [0]

Dige: Hemi: *Parahemiurus merus* (Linton, 1910) Manter, 1940 (digestive tract) [0] (NHR)

Dige: Opec: *Macvicaria macassarensis* (digestive tract) [0]

Dige: Opec: *Neolebouria* sp. A (digestive tract) [0]

Dige: Opec: *Pseudoplagioporus interruptus* Durio & Manter, 1968 (digestive tract) [0]

Dige: Opec: *Pseudoplagioporus lethrini* Yamaguti, 1938 (digestive tract) [0] (NHR)

Both: Unid: larvae (abdominal cavity) [0]

Tetr: Unid: larvae (digestive tract) [0]

Tryp: Laci: *Callitetrarhynchus gracilis* (Rudolphi, 1819) Pintner, 1931 (abdominal cavity) [0] (NHR)

Tryp: Laci: *Floriceps minacanthus* Campbell & Beveridge, 1987 (abdominal cavity) [0] (NHR)

Tryp: Laci: *Pseudogilquinia microbothria* (Mac Callum, 1917) Palm, 2004 (abdominal cavity) [0] (NHR)

Tryp: Laci: *Pseudolacistorhynchus heroniensis* (abdominal cavity) [0] (NHR)

Nema: Anis: *Raphidasca* sp. (digestive tract) [0]

Nema: Anis: unidentified larvae (digestive tract) [0]

Nema: Cucu: *Dichelyne* sp. (digestive tract) [0]

Nema: Phil: *Philometra lethrini* (digestive tract) [9]

Acan: unidentified (digestive tract) [0]

Remarks: 31 specimens examined (15 for gills, 27 for abdominal organs).
HPCs: 31; SLIP-HPCs: 16.

***Lethrinus nebulosus* (Forsskål)**

Cope: Hats: *Hatschekia gracilis* Yamaguti, 1954(gills) [0] (NHR)

Cope: Hats: *Hatschekia* n. sp. 13 (gills) [0]

Cope: Hats: *Hatschekia* n. sp. 15 (gills) [0]

Mono: Ancy: *Haliotrema* sp. 1 (gills) [13]

Mono: Caps: *Encotyllabe* sp. (pharyngeal teeth) [0]

Mono: Dipl: *Calydiscoides difficilis* (gills) [13]

Mono: Dipl: *Calydiscoides duplicostatus* (gills) [13]

Mono: Dipl: *Calydiscoides terpsichore* (gills) [13]

Poly: Micr: unidentified immature (gills) [6]

Dige: Opec: *Macvicaria macassarensis* (digestive tract) [0] (NHR)

Leca: Unid: unidentified larva (gills) [0]

Remarks: 14 specimens examined (8 for gills, 14 for abdominal organs).

HPCs: 11; SLIP-HPCs: 5.

***Lethrinus obsoletus* (Forsskål)**

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Cope: Hats: *Hatschekia gracilis* (gills) [0] (NHR)

Mono: Ancy: *Haliotrema* sp. (gills) [0]

Mono: Caps: *Encotyllabe* sp. (pharyngeal teeth) [0]

Mono: Dipl: *Calydiscoides difficilis* (gills) [13]

Remarks: 3 specimens examined (3 for gills, 3 for abdominal organs).

HPCs: 5; SLIP-HPCs: 2.

***Lethrinus ravus* Carpenter & Randall, 2003**

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Mono: Ancy: *Haliotrema* sp. (gills) [0]

Mono: Dipl: *Calydiscoides difficilis* (gills) [13]

Dige: Opec: *Neolebouria* sp. A (digestive tract) [0]

Nema: Cama: *Procamallanus* (*Spirocamallanus*) sp. 2 of Moravec *et al.*, 2006, subgravid female (digestive tract) [11]

Remarks: 3 specimens examined (2 for gills, 1 for abdominal organs).

HPCs: 5; SLIP-HPCs: 1.

***Lethrinus rubrioperculatus* Sato, 1978**

Isop: Gnat: unidentified Praniza larvae (gills) [0]

Cope: Cali: *Caligus lethrinicola* Boxshall & El-Rashidy, 2009 (gills) [1]

Cope: Lern: *Sagum vespertilio* Kabata, 1979 (gills) [0] (NHR)

Mono: Ancy: *Haliotrema* sp.a (gills) [6]

Mono: Ancy: *Haliotrema* sp. b (gills) [6]

Mono: Caps: *Encotyllabe* sp. 1 of Perkins, 2010 (pharyngeal teeth) [12]

Mono: Caps: *Capsalidae* sp. 11 of Perkins, 2010 (head) [12]

Mono: Dipl: *Calydiscoides euzeti* Justine, 2007 (gills) [6]

Dige: Acan: *Stephanostomum aaravi* (digestive tract) [3]

Dige: Didy: unidentified larva (gills) [0]

Dige: Hemi: *Lecithochirium* sp. (digestive tract) [0]

Dige: Hemi: *Tubulovesicula angusticauda* (digestive tract) [0] (NHR)
Dige: Opec: *Helicometra* sp. (digestive tract) [0]
Dige: Opec: *Macvicaria* sp. (digestive tract) [0]
Dige: Opec: *Neolebouria* sp. A (digestive tract) [0]
Dige: Opec: *Pseudoplagioporus interruptus* (digestive tract) [0] (NHR)

Tetr: Unid: larvae (digestive tract) [0]

Tryp: Otob: *Otobothrium parvum* Beveridge & Justine, 2007 (abdominal organs) [0] (NHR)
Tryp: Tent: *Nybelinia goreensis* (abdominal organs) [6] (as *Nybelinia* sp.)

Acan: unidentified (digestive tract) [0]

Remarks: 97 specimens examined (49 for gills, 66 for abdominal organs).
HPCs: 20; SLIP-HPCs: 8.

***Lethrinus variegatus* Valenciennes**

Mono: Ancy: *Haliotrema* sp. (gills) [0]

Dige: Opec: *Neochoanostoma* sp. A (digestive tract) [0]
Dige: Opec: *Neochoanostoma* sp. B (digestive tract) [0]

Tetr: Unid: larvae (digestive tract) [0]

Nema: Anis: unidentified larvae (digestive tract) [0]
Nema: Cama: *Procamallanus (Spirocamallanus) monotaxis* (digestive tract) [0] (NHR)
Nema: Phil: *Philometra lethrini* (gonads) [9]

Remarks: 7 specimens examined (4 for gills, 5 for abdominal organs).
HPCs: 7; SLIP-HPCs: 2.

***Lethrinus xanthochilus* Klunzinger**

Cope : Unid: unidentified larvae (gills) [6]

Mono: Ancy: *Haliotrema* sp. (gills) [6]
Mono: Caps: *Encotyllabe* sp (pharyngeal teeth) [6]
Mono: Dipl: *Calydiscoides euzeti* (gills) [6]

Remarks: 1 specimen examined (1 for gills, 0 for abdominal organs).
HPCs: 4; SLIP-HPCs: 1.

Appendix 2. Parasite-host list.

For each group evaluators of biodiversity are indicated.

Minimized number of taxa: the number of taxa (basically the number of different paragraphs in the section), counting all records as 1 taxon (including multiple undistinguishable taxa, such as larvae, as 1).

Number of SLIPs: number of species-level identified parasite species; includes only species with binomials.

Number of non-SLIP taxa: number of parasite species which could be differentiated but did not receive a binomial name; these include 'cf' taxa, numbered taxa, and 'sp.' taxa unique in their genus.

Undistinguishable larval taxa: with a mention of the family involved and the possible number of species.

Note: Minimized number of taxa = SLIPs + no-SLIP taxa + unidentified taxa + undistinguishable larvae.

New host records (NHR) are indicated only for SLIPs.

Isopoda

Minimized number of taxa: 1

Number of SLIPs: 0

Number of non-SLIP taxa: 0

Undistinguishable larval taxa: 1 (gnathiids)

Gnat: Praniza larvae

Gymnocranius grandoculis

Lethrinus atkinsoni

Lethrinus genivittatus

Lethrinus harak

Lethrinus lentjan

Lethrinus miniatus

Lethrinus obsoletus

Lethrinus ravus

Lethrinus rubrioperculatus

Hats: *Hatschekia gracilis*

Lethrinus nebulosus (NHR)

Lethrinus obsoletus (NHR)

Hats: *Hatschekia megacephala*

Gymnocranius grandoculis (NHR)

Hats: *Hatschekia* n. sp. 12

Gymnocranius euanus

Hats: *Hatschekia* n. sp. 13

Lethrinus nebulosus

Hats: *Hatschekia* n. sp. 14

Gymnocranius grandoculis

Hats: *Hatschekia* n. sp. 15

Lethrinus harak

Lethrinus nebulosus

Hats: *Hatschekia* n. sp. 16

Lethrinus miniatus

Cali: *Caligus lethrinicola*

Lethrinus rubrioperculatus

Hats: *Hatschekia rotundigenitalis*

Gymnocranius euanus (NHR)

Gymnocranius grandoculis (NHR)

Cali: *Caligus* n. sp. 1

Gymnocranius grandoculis

Lern: *Sagum vespertilio*

Lethrinus rubrioperculatus (NHR)

Cali: *Caligus novocaledonicus*

Gymnocranius euanus (NHR)

Gymnocranius grandoculis (NHR)

Gymnocranius oblongus (NHR)

Lerp: *Parabrachiella* sp. 1

Gymnocranius euanus

Unidentified family: unidentified larvae

Lethrinus xanthochilus

Diss: *Dissonus excavatus*

Lethrinus miniatus (NHR)

Hats: *Hatschekia* cf. *elegans*

Lethrinus miniatus

Monopisthocotylea

Minimized number of taxa: 23 [Counting 5 *Haliotrema* species and 2 *Encotyllabe* species, including *E. caballeroi*]

Number of SLIPs: 11

Number of non-SLIP taxa: 11

Undistinguishable larval taxa: 0

Ancy: *Haliotrema* sp. (5 spp.)
Lethrinus harak (3 spp)
Lethrinus lentjan
Lethrinus miniatus
Lethrinus nebulosus
Lethrinus obsoletus
Lethrinus ravus
Lethrinus rubrioperculatus (2 spp.)
Lethrinus variegatus
Lethrinus xanthochilus

Caps: Capsalidae sp. 8
Gymnocranius grandoculis

Caps: Capsalidae sp. 10
Lethrinus miniatus

Caps: Capsalidae sp. 11
Lethrinus rubrioperculatus

Caps: Capsalidae sp. 16
Lethrinus miniatus

Caps: *Encotyllabe caballeroi*
Lethrinus miniatus

Caps: *Encotyllabe* sp.
Lethrinus harak
Lethrinus nebulosus
Lethrinus obsoletus
Lethrinus xanthochilus
Lethrinus rubrioperculatus
Gymnocranius grandoculis
Gymnocranius euanus
Gymnocranius oblongus
Gymnocranius sp. B

Caps: unidentified
Gymnocranius euanus
Lethrinus genivittatus

Dipl: *Calydiscoides australis*
Lethrinus miniatus

Dipl: *Calydiscoides difficilis*
Lethrinus harak
Lethrinus lentjan
Lethrinus nebulosus
Lethrinus obsoletus
Lethrinus ravus

Dipl: *Calydiscoides duplicostatus*
Lethrinus harak
Lethrinus lentjan
Lethrinus nebulosus

Dipl: *Calydiscoides euzeti*
Lethrinus rubrioperculatus

Lethrinus xanthochilus

Dipl: *Calydiscoides gussevi*
Lethrinus miniatus

Dipl: *Calydiscoides rohdei*
Lethrinus atkinsoni

Dipl: *Calydiscoides terpsichore*
Lethrinus harak
Lethrinus nebulosus

Dipl: *Lamellodiscus magnicornis*
Gymnocranius euanus
Gymnocranius grandoculis
Gymnocranius oblongus
Gymnocranius sp. B

Dipl: *Lamellodiscus parvicornis*
Gymnocranius euanus
Gymnocranius grandoculis
Gymnocranius sp. B

Dipl: *Lamellodiscus* sp.
Gnathodentex aureolineatus

Dipl: *Lamellodiscus tubulicornis*
Gymnocranius grandoculis
Gymnocranius sp. B

Polyopisthocotylea

Minimized number of taxa: 1
Number of SLIPs: 0
Number of non-SLIP taxa: 1
Undistinguishable larval taxa: 0

Micr: unidentified
Gymnocranius euanus
Gymnocranius grandoculis
Gymnocranius oblongus
Lethrinus nebulosus

Digenea

Minimized number of taxa: 27
Number of SLIPs: 13
Number of non-SLIP taxa: 13
Undistinguishable larval taxa: 1 (didymozoids: 20?)

Acan: *Stephanostomum aaravi*
Lethrinus miniatus
Lethrinus rubrioperculatus

Acan: *Stephanostomum japonocasum*
Lethrinus miniatus

Bive: *Bivesicula* sp.
Lethrinus genivittatus

Didy: unidentified adult
Gymnocranius euanus
Gymnocranius grandoculis
Gymnocranius oblongus
Lethrinus harak
Lethrinus miniatus

Didy: unidentified larvae
Gymnocranius euanus
Gymnocranius grandoculis
Lethrinus rubrioperculatus

Hemi: *Elytrophalloides oatesi*
Gymnocranius euanus (NHR)
Lethrinus miniatus (NHR)

Hemi: *Lecithochirium* sp.
Lethrinus genivittatus
Lethrinus miniatus
Lethrinus rubrioperculatus

Hemi: *Parahemiurus merus*
Lethrinus miniatus (NHR)

Hemi: *Tubulovesicula angusticauda*
Gymnocranius euanus
Lethrinus rubrioperculatus

Opec: *Helicometra* sp.
Lethrinus rubrioperculatus

Opec: *Macvicaria macassarensis*
Lethrinus atkinsoni (NHR)
Lethrinus miniatus
Lethrinus nebulosus (NHR)

Opec: *Macvicaria* sp.
Lethrinus genivittatus
Lethrinus rubrioperculatus

Opec: *Nechoanostoma avidabira*
Gymnocranius euanus (NHR)
Gymnocranius grandoculis (NHR)
Gymnocranius oblongus (NHR)
Gymnocranius sp. B (NHR)

Opec: *Nechoanostoma bariadiva*
Gymnocranius sp. B (NHR)

Opec: *Nechoanostoma* sp.
Gymnocranius grandoculis
Gymnocranius sp. C
Lethrinus genivittatus

Opec: *Nechoanostoma* sp. A
Gymnocranius euanus

Opec: *Nechoanostoma* sp. B
Gymnocranius euanus

Opec: *Neolebouria* sp. A
Lethrinus atkinsoni
Lethrinus miniatus
Lethrinus ravus
Lethrinus rubrioperculatus
Lethrinus variegatus

Opec: *Neolebouria* sp. B
Lethrinus genivittatus
Lethrinus lentjan
Lethrinus variegatus

Opec: *Orthodena* sp.
Lethrinus harak

Opec: *Orthodena tropica*
Lethrinus genivittatus (NHR)
Lethrinus lentjan (NHR)

Opec: *Propycnadenoides philippinensis*
Gymnocranius euanus (NHR)
Gymnocranius grandoculis (NHR)
Gymnocranius oblongus (NHR)
Gymnocranius sp. B (NHR)

Opec: *Pseudoplagioporus interruptus*
Lethrinus miniatus
Lethrinus rubrioperculatus (NHR)

Opec: *Pseudoplagioporus lethrini*
Lethrinus miniatus (NHR)

Tran: *Transversotrema* sp.
Gymnocranius euanus
Gymnocranius grandoculis

Zoog: *Zoogonus pagrosomi*
Lethrinus atkinsoni
Lethrinus genivittatus

Zoog: *Zoogonus* sp.
Gymnocranius euanus

Cestoda Bothriocephalidea
Minimized number of taxa: 1
Number of SLIPs: 0
Number of non-SLIP taxa: 0
Undistinguishable larval taxa: 1 (possibly 50?)

Unidentified family: unidentified larvae
Lethrinus miniatus

Cestoda Lecanicephalidea
Minimized number of taxa: 1

Number of SLIPs: 0
Number of non-SLIP taxa: 0
Undistinguishable larval taxa: 1 (possibly 20?)
Note: grouped with Tetraphyllidea in Table 3 (see below)

Unidentified family: unidentified larvae
Lethrinus nebulosus

Cestoda Tetraphyllidea

Minimized number of taxa: 1
Number of SLIPs: 0
Number of non-SLIP taxa: 0
Undistinguishable larval taxa: 1 (possibly 50?)
Note: grouped with Lecanicephalidea in Table 3, as
Minimized number of taxa: 2; Number of SLIPs: 0;
Number of non-SLIP taxa: 0; Undistinguishable
larval taxa: 2]

Unidentified family: unidentified larvae
Gymnocranius euanus
Lethrinus atkinsoni
Lethrinus genivittatus
Lethrinus miniatus
Lethrinus rubrioperculatus
Lethrinus variegatus

Cestoda Trypanorhyncha

Minimized number of taxa: 8
Number of SLIPs: 6
Number of non-SLIP taxa: 0
Undistinguishable larval taxa: 2 (2)

Eute: unidentified larvae
Lethrinus genivittatus

Laci: *Callitetrarhynchus gracilis* larvae
Lethrinus miniatus (NHR)

Laci: *Floriceps minacanthus* larvae
Lethrinus miniatus (NHR)

Laci: *Pseudogilquinia microbothria* larvae
Lethrinus miniatus (NHR)

Laci: *Pseudolacistorhynchus heroniensis* larvae
Gymnocranius grandoculis (NHR)
Lethrinus miniatus (NHR)

Otob: *Otobothrium parvum* larvae
Lethrinus rubrioperculatus (NHR)

Tent: *Nybelinia goreensis* larvae
Lethrinus genivittatus (NHR)
Lethrinus rubrioperculatus (NHR)

Unidentified family: unidentified larvae
Gymnocranius euanus

Nematoda

Minimized number of taxa: 10
Number of SLIPs: 5
Number of non-SLIP taxa: 4
Undistinguishable larval taxa: 1 (anisakids: possibly 10?)

Anis: *Raphidascaris* sp.
Lethrinus genivittatus
Lethrinus miniatus

Anis: unidentified larvae
Gymnocranius euanus
Gymnocranius grandoculis
Gymnocranius sp. B
Lethrinus lentjan
Lethrinus miniatus
Lethrinus variegatus

Cama: *Procamallanus (Spirocamallanus) monotaxis*
Lethrinus genivittatus (NHR)
Lethrinus variegatus (NHR)

Cama: *Procamallanus (Spirocamallanus)* sp. 2
Lethrinus ravus

Cucu: *Dichelyne* sp.
Lethrinus miniatus

Cyst: *Ascarophisnema tridentatum*
Gymnocranius euanus
Gymnocranius sp. C (NHR)

Gnto: *Echinocephalus* sp.
Lethrinus genivittatus

Phil: *Philometra lethrini*
Lethrinus genivittatus
Lethrinus miniatus
Lethrinus variegatus

Tric: *Huffmanella filamentosa*
Gymnocranius grandoculis

Tric: *Huffmanella longa*
Gymnocranius grandoculis
Gymnocranius oblongus (NHR)

Acanthocephala

Minimized number of taxa: 1
Number of SLIPs: 0
Number of non-SLIP taxa: 1
Undistinguishable larval taxa: 0

Unidentified family: unidentified
Lethrinus miniatus
Lethrinus rubrioperculatus

Hirudinea

Minimized number of taxa: 1

Number of SLIPs: 0

Number of non-SLIP taxa: 1

Undistinguishable larval taxa: 0

Unidentified family: unidentified

Lethrinus harak

Appendix 3. Material deposited.

*: type material.

Pisces

Gymnocranius euanus, MNHN 2005-0769; 2006-1328.

Lethrinus atkinsoni, MNHN 2005-0773; 2006-1329; 2006-1636.

Lethrinus ravus, MNHN 2006-1637; 2006-1638; 2006-1639.

Lethrinus rubrioperculatus, MNHN 2005-0770; 2005-0771; 2006-1325; 2006-1335; 2006-1640.

Copepoda

Caligus lethrinicola ex *L. rubrioperculatus*, MNHN Cp2969.

Monogenea (all Monopisthocotylea)

Caps: Capsalidae sp. 8 of Perkins (2010) ex branchiostegal membranes *G. grandoculis* (JNC2711), SAMA AHC 29708.

Caps: Capsalidae sp. 11 of Perkins (2010) ex head *L. rubrioperculatus* (JNC2726), SAMA AHC 29711.

Caps: Capsalidae sp. 16 of Perkins (2010) ex body washings *L. miniatus* (JNC2184), SAMA AHC 29715.

Caps: *Encotyllabe caballeroi* (see Perkins 2010) ex pharyngeal teeth *L. miniatus* (JNC2705), SAMA AHC 29719.

Caps: *Encotyllabe* sp. 1 (see Perkins 2010) ex pharyngeal teeth *L. rubrioperculatus* (JNC2715), SAMA AHC 45382 (spirit voucher).

Caps: *Encotyllabe* sp. 2 (see Perkins 2010) ex pharyngeal teeth *G. grandoculis* (JNC2711), SAMA AHC 29720.

Caps: *Encotyllabe* sp. 3 (see Perkins 2010) ex pharyngeal teeth *G. euanus* (JNC2712), SAMA AHC 29721.

Dipl: *Calydiscoides difficilis* ex *L. harak*, MNHN JNC1750–1752, JNC1770–1772, BMNH 2006.12.13.3, USNPC 99433, MPM 18847, HCIP M-428/2; ex *L. lentjan*, MNHN JNC334-335; ex *L. nebulosus*, MNHN JNC 967, BMNH 2006.12.13.4–5, USNPC 99432, MPM 18845–6, HCIP M-428/1; ex *L. ravus*, MNHN JNC1761, JNC1763; ex *L. obsoletus*, MNHN JNC1829, BMNH 2006.12.13.2, USNPC 99434, MPM 18848, HCIP M-428/3.

Dipl: *Calydiscoides duplicostatus* ex *L. harak*, MNHN JNC1770–1772, JNC1784; ex *L. lentjan*, MNHN JNC334-335; ex *L. nebulosus*, MNHN JNC 967, JNC1785.

Dipl: *Calydiscoides euzeti* ex *L. rubrioperculatus*, MNHN JNC989*, BMNH 2006.12.13.9*, USNPC 99428*, MPM 18841*, HCIP M-424*; ex *L. xanthochilus*, MNHN JNC1773*.

Dipl: *Calydiscoides gussevi* ex *L. miniatus*, MNHN JNC1924, BMNH 2006.12.13.8, USNPC 99428, MPM 18842, HCIP M-425.

Dipl: *Calydiscoides rohdei* ex *L. atkinsoni*, MNHN JNC1776, BMNH 2006.12.13.6, USNPC 99430, MPM 18843, HCIP M-426.

Dipl: *Calydiscoides terpsichore* ex *L. nebulosus*, MNHN JNC967*, JNC1985*; BMNH 2006.12.13.7*, USNPC 99431*, MPM 18844*, HCIP M-427*; ex *L. harak*, MNHN JNC1770*, JNC1771*, JNC1784*.

Dipl: *Lamellodiscus tubulicornis* ex *G. grandoculis*, MNHN JNC1726*, JNC1246*, JNC1617*, BMNH 2009.9.18.2*, USNPC 102287*.

Dipl: *Lamellodiscus tubulicornis* ex *G. grandoculis*, MNHN JNC1726*, JNC1246*, JNC1617*, BMNH 2009.9.18.3*, USNPC 102288*.

Dipl: *Lamellodiscus parvicornis* ex *G. euanus*, MNHN JNC1549*, BMNH 2009.9.18.4*, USNPC 102289*.

Dipl: *Lamellodiscus* sp. ex *Gnathodentex aureolineatus*, MNHN JNC1485.

Digenea

Acan: *Stephanostomum aaravi* ex *L. miniatus*, MNHN JNC2402, JNC1885, JNC2773

Acan: *Stephanostomum japonocasum* ex *L. miniatus*, MNHN JNC2205, JNC2207, JNC2300, JNC2822B.

Zoog: *Zoogonus pagrosomi* ex *L. atkinsoni*, MNHN JNC1789; ex *L. genivittatus*, MNHN JNC2293, BMNH 2007.11.14.52.

Nematoda

Cama: *Procamallanus* (*Spirocamallanus*) *monotaxis* ex *L. genivittatus*, MNHN JNC643, JNC643C, JNC644A, JNC645B, JNC646B, JNC647A, JNC647B, JNC648A, JNC653A, JNC658A, JNC659A, JNC1959A, JNC1959B, JNC1960, JNC2022, JNC2030, JNC2031B, JNC2033, JNC2031B, JNC2033, JNC2077, JNC2228, JNC2229, JNC2230, JNC2231, JNC2232, JNC2234, JNC2236, JNC2237, JNC2239, JNC2240, JNC2241, JNC2242, JNC2243, JNC2244, JNC2245, JNC2246, JNC2247, JNC2250, JNC2317D, JNC2321, JNC2327, JNC2507, HCIP N-952 ; ex *L. variegatus*, MNHN JNC2077.

Cama: *Procamallanus* (*Spirocamallanus*) sp. 2 ex *L. ravus*, JNC1286.

Cucu: *Dichelyne* sp. ex *L. miniatus*, MNHN JNC2455.

Cyst: *Ascarophisnema tridentatum* ex *G. euanus*, MNHN JNC3024*, JNC3063*, HCIP N-932*; ex *Gymnocranius* sp. C, MNHN JNC3055*.

Phil: *Philometra lethrini* ex *L. genivittatus*, MNHN JNC2032*, JNC2317C, JNC2328, HCIP N-897*; ex *L. miniatus*, MNHN JNC2113D; ex *L. variegatus*, MNHN JNC2077.

Tric: *Huffmanella filamentosa* ex *G. grandoculis*, MNHN JNC892A*, HCIP N-817*, BMNH 2004.2.18.2*, SAMA AHC 32857*.

Tric: *Huffmanella longa* ex *G. grandoculis*, MNHN JNC1726, JNC2166, HCIP N-881, BMNH 2007.7.12.2, USNPC 99978, SAMA AHC 34776; ex *G. oblongus*, MNHN JNC2174*.